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ABSTRACT

The final volume of a six-volume final report (which covers the findings of a research project on policy and technology related to rehabilitation of disabled individuals) examines the methodology and findings of the geometric-simulation modeling effort which support the consequence- and policymaking-analysis efforts of the technology assessment team. Initial sections discuss the general procedure, plan, and strategy of the modeling initiative. The methodologies employed to facilitate model formulation and their relative utility are reviewed. In a section on the models developed, subsections describe the GSIM (geometric simulation model) and Forester-style approaches. A final section summarizes conclusions which corroborate, substantiate, or justify the recommendations found in Volume I (EC 104 673), Chapter 7 and conclusions about the appropriateness of modeling as a contributing component in any technology assessment endeavor. Documentation, including descriptions and listings, of all computer codes developed in the research activity is appended. (SBH)

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HUMAN REHABILITATION TECHNIQUES

A Technology Assessment

Burns, J.R.　　　　Marcy, W.M.

TEXAS TECH UNIVERSITY

Volume VI

Supplemental Report:
Modeling Rehabilitation

EC104174

FOREWORD

This document is the sixth volume of the final report *Technology Assessment: Human Rehabilitation Techniques,* a project conducted at Texas Tech University by the Department of Industrial Engineering, the Research and Training Center in Mental Retardation, the Department of Systems, and the Technical and Professional Writing Program. The research has been conducted with the support of National Science Foundation grants ERP 75-10594 and ERP 75-10594 A01, monitored by the Directorate for Research Applications, Division of Exploratory Research and Systems Analysis.

Richard A. Dudek, Horn Professor and Chairman of the Department of Industrial Engineering has been a co-principal investigator and director of the project. Gerard J. Bensberg, Director of the Research and Training Center in Mental Retardation, and M. M. Ayoub, Professor of Industrial Engineering, have been co-principal investigators. Carol M. Sigelman and Andrew S. Martin of the Research and Training Center in Mental Retardation and Robert F. Powers of the Department of Industrial Engineering have been program managers for the project. James R. Burns and William M. Marcy of the Department of Systems have been in charge of the modeling used in the project. Technical writing has been performed by Charles W. Brewer and Cynthia E. Lyle of the Technical and Professional Writing Program. In addition, several research assistants and support personnel, as listed in the individual volumes of the study, have contributed to the project.

The project team wishes to acknowledge the efforts of individuals who have served on the Oversight Committee, Elizabeth Boggs, Kan Chen, Beatrix Cobb, Ronald Conley, Richard Herman, John Noble, Jr., Evan Vlachos, and Lester Wolcott; of Lee Phillips who served effectively as a program manager for a short time before leaving Texas Tech; of Brian Lambert who served as Work Session Conference Coordinator; of those who participated in the work-sessions chaired by Ted Hartman, David Malone, Blair Rowley, Evan Vlachos and John Wittman; and of Anne Seitz, the Secretary of the Project.

Although the National Science Foundation has supported this project, the findings, conclusions and recommendations expressed are those of the research team and do not necessarily reflect the views of NSF.

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Introduction

Described in this volume and elsewhere (see Volumes 1 and 5) is the research performed under a study proposed as an adjunct to the technology assessment project concerned with technologies applied to rehabilitate disabled persons in the United States. As stated in the abstract of the adjunct proposal [1], the purpose of the research described herein was "to utilize exploratory computer studies to assist in structuring the problem and in assessing the impacts of various policy alternatives". This report provides an explanation of how that objective was accomplished and what results were obtained from the achievement of the objective.

Before discussing procedure, methodology, model assumptions, structure, and results, however, it is appropriate to remark at this time regarding the relationship of these studies to the parent project. These studies were initiated some 9 months after the start of this parent project. Much in the way of data had already been collected in assorted reports. It was soon discovered that, even though a "mountain" of information was available, there were important data items that simply were not available anywhere. This was particularly true with regard to costs associated with technologies.

But there were other facets of these studies that made the modelers' task even more difficult. For example, most of the fourteen case study disabilities picked by the parent project lacked age and sex-specific demographic statistics, and there were many important variables which, because of their "softness", lacked precise definitions and therefore defied quantifiability. The definition of accessibility of public buildings is an example of a variable which lacks precision. Many new buildings proudly display at their entrances an emblem which marks them as accessible by wheelchair patients. These same buildings are not accessible by all disabled persons, such as the blind, the lack of hearing, or the bedridden patient. Clearly, such buildings are not accessible if a strict definition is applied. The softness of the great many variables associated with the problem of human rehabilitation make it difficult to model.

A still further example of the ambiguities encountered in this modeling endeavor is the concept of rehabilitation. Once a disabled individual is rehabilitated, is he still counted as a member of the disabled population or is he now counted among the healthy population? Or is there yet a third population --- into which this individual is now placed? If it is presumed that he "leaves" the disabled population once rehabilitated, at what life function level[1] does this exit take place, assuming that all rehabilitation programs have as their

---

1) Conversely, when a disability occurs, at what life function level does the new entrance into the disabled group take place?

basic goal the improvement of life functions? These issues will be dealt with in detail later in the report.

In endeavoring to develop a formal model of the rehabilitation problem a subsystem approach was taken [2]. Specifically, there are five subsystems that are considered in the model --- a scenario sector, a program thrust and technology sector, a life-function sector, a demographic sector, and a consequence sector.

A consideration of each of these sectors led to an improved understanding of the detail and kinds of data required. It was discovered that specific data on the relationship of life-functions to such "consequence variables" as disabled employed, disabled income, status of the disabled, and disabled productivity would have to be contrived. Also the relationship of technologies to life-functions and of program thrusts to life-functions needed further quantification. The results of studies intended to clarify these issues are described in what follows.

These questions are indicative of the myriad issues that were confronted while formulating formal models of the problem. Summarily, the use of formal modeling in connection with technology assessment activities forces 1) a holistic approach to the problem, 2) a consideration of the important issues relating to the whole, and 3) a comprehension for the data required to comprehensively characterize the various components which comprise the whole.

In subsequent sections of this report many such significant issues are confronted. In addition, specific definitional problems are considered together with suggestions for their resolution. The general procedure, plan, and strategy of the modeling initiative is discussed first. Described in this section was the modeler's participation in the development of the specific work-session procedures used. In order to insure that useful information (regarding the underlying causality for each program thrust considered) was obtained, the modelers advocated the use of causal modeling procedures in the work-sessions. Not only did this and similar innovations facilitate gathering data for the models, but served as a powerful cognitive device capable of stimulating panelists' participation, communicating concepts, and preventing structural errors of commission and omission (See Appendix II).

Discussed next are the methodologies employed to facilitate model formulation and their relative utility. The modelers found it often necessary to develop their own methodologies in order to proceed with a logical formulation of the models. Extensions of the existing methodologies, bridging gaps between conventional techniques, was undertaken not once but several times in order to accomplish the task of formal model formulation. These activities are described in the section on methodologies.

The discussion about methodologies is followed by a description of the models that were developed. Many assumptions had to be made in order to facilitate formulation of the models. These are described in the section on modeling. The modeling activities were largely devoted to the use of GSIM [3] and Forrester-style [4] approaches. Therefore, the section on modeling consists of subsections which describe the GSIM models and the Forrester model. Both the structure and the behavioral results of the Forrester model are described.

The modeling subsections are followed by the last section of the report -- conclusions. Conclusions are of two types. First conclusions which corroborate, substantiate, or justify the recommendations found in Volume 1, Chapter7 are provided. Additional detail is added to some of the recommendations. Then conclusions about the appropriateness of modeling as a contributing component in any technology assessment endeavor, and what can be learned that would not have been learned if modeling had not been used, are deduced or inferred.

Finally, documentation, including descriptions and listings, of all computer codes developed in this research activity are provided as appendices to this report.

Procedure

The general plan of the modeling initiative of this technology assessment was to extract the necessary information from work sessions, project papers, other studies, and other models. These inputs would then be incorporated into causal or interaction digraphs which could later be translated into dynamic simulation models. These models would be driven by the various scenario specifications. The results could then be compared and discussed. Conclusions and policy considerations could then be developed.

The specifics of carrying out this plan necessitated that special consideration be given to the methodology used in the work sessions to ensure the success of the data collection for the model formulation. It was decided that the use and generation of "causal diagrams" (elsewhere referred to as hierarchical and interrelationship models) would serve to structure and organize the collective assessments of the workshop session participants into a model. It was found that use of this technique served as a powerful heuristic for focusing each group's attention upon the issues central to the program thrust being considered.

These causal models were then used to generate GSIM simulations. The simulation results were then shown to the work session participants for their consideration. Such consideration led to changes in structure intended to produce behaviors which were more consistent with the collective understanding of behavior. This procedure expedited the development of GSIM simulations for the various technology groups and enhanced the participants' capability 1) to generate consequences and 2) to understand the important issues which interact to produce the behaviors of interest.

Each work-session developed its own GSIM model. Following the work-sessions, the models were further refined and generalized (so as to extend the scope of their applicability to all program thrusts within a particular technology area) using after-session inputs from the session participants. The refined models were then each driven by historical and extrapolated time series data for scenario variables *societal capability*, *tax willingness*, *funds to social needs*, and *disabled population*. Three specific sets of scenario data for each of the three base scenarios were used in this context. In addition runs were then made to generate results under "constrained" situations in which an upper limit or "threshold" was established for the scenario variable *tax willingness*. The results are briefly summarized in the work-session reports (Volume 5).

Using these work-session models a comprehensive variable list was compiled and this list was used to formulate a comprehensive GSIM model. The comprehensive or "generic" GSIM model is described in detail elsewhere (See Volume 1, Chapter 6).

The generic model structure then partially influenced the development of the consequence sector within the Forrester-style model. However, other sectors of the Forrester-style model were developed independently as shall be discussed in a subsequent section.

Methodology

Consistent with the intent of the proposal specifying the study content of this initiative, the modeling activity has identified and tried several modeling methodologies which were utilized to a greater or lesser extent in this technology assessment.

Most useful within the work-sessions was the causal modeling technique. As used therein, the participants were allowed to simultaneously generate elements and linkages between the elements. This simultaneous generation of quantities and couplings was found to most usefully expedite the development of a causal model and its GSIM counterpart.

Other techniques (namely interpretive structural modeling [5]) require participants to generate a list of elements before any links between elements are specified. For our purposes, these latter techniques were found to be relatively less useful because of the time constraints we were working with. Specifically, interpretive structural modeling exercises were somewhat less useful for our purposes because they 1) tended to emphasize the hierarchical aspects of the systems to the detriment of the feedback aspects, 2) were too time-consuming to be practically accomplished within the time frame allocated, and, 3) did not provide any indication as to behavior of the dynamic systems being worked with.

Inherently useful to the consequence generation activities within the work-sessions were the GSIM [4] (See Appendix I for a short description of GSIM) simulations. These enhanced understanding of the dynamical system and broadened the participants' comprehension of the spectrum of possible consequences (many of which had been overlooked by conventional consequence generation activities). The work-session reports (Volume 5) describe the computer-generated consequences, their implications and interpretations.

In the process of developing these models considerable confusion arose as to the meaning of the causal linkage. All panelists generally applied the notion of influence or causation to the coupling in the sense that a coupling directed from q_i toward q_j expresses the verbal notion that "q_i somehow causes, affects, or has an influence on q_j". In considering the coupling in greater detail, it was discovered first that the literature was noticeably silent and unhelpful on the subject. Close scrutiny of the dozens of causal linkages postulated led to the conclusion that essentially two mutually distinct types of causation exist between any pair of quantities (q_i, q_j) that are interactant by means of a causal link. As a result, it is now believed that, for any causal relation R(Q,Q) defined on the Cartesian product Q x Q where Q represents a set of quantities, the elements of the set R can be partitioned into two types.

The first type is referred to as accumulative causality whereas the second type is called proportional causality (See Appendix I). It was also discovered that these two types are analogous to the α_{ij} and β_{ij} interactions defined in Kane's methodology [6] and the flow and information mechanisms postulated in the Forrester [7] methodology. Further details about this discovery, and the use of causal models in connection with cross-impact or interaction matrices can be found in [3] (See also Appendix II).

As previously mentioned the various GSIM simulations developed by the work-sessions were aggregated into a generic GSIM model. This aggregation process is described in Volume 1, Chapter 6, but essentially involved a study of the commonality of variable types and the possibility for aggregation of various quantities under a single generic quantity name.

As discussed in the section on procedure, the generalized or generic model was thereafter used to facilitate formulation of the formal Forrester-style model. Since the relationship between Kane-style models and Forrester-style models was not well understood, it was necessary for the modelers to develop a theory (See Appendix II and Reference 3) regarding the relationship, and to utilize the theory to evolve the transition. In addition to the generalized GSIM model, data from other activities of the parent technology assessment was incorporated into the Forrester model. For example, the related contexts project paper (Volume 4) was used to specify scenario variables and scenario behaviors. The related data project paper (Volume 4) was used to specify needed information on demographic statistics and funds allocated for rehabilitation. The project papers on life-functions (also Volume 4) and rehabilitation technologies provided essential inputs in these respective areas.

To summarize, both modelers and participants found the modeling activities within the work-sessions to be of significant value in enhancing understanding of the system and of generating consequences for given policy-scenario combinations. The specific modeling techniques found to be useful in this context were causal modeling and GSIM. Interpretive structural modeling was found to be considerably less useful, given the needs and concerns at the time.

The Models

Assumptions.

All models discussed in this volume and elsewhere are premised upon the presumption that the task of rehabilitation is technology intensive, in the sense that technology alone is able to cope with and ameliorate the problems associated with human disability and impairment in any of its forms. The word "technology" as used here is intended to take on a broadened understanding as referring to any project, device, program, or initiative which is instituted for the purpose of rehabilitation, so the presumption is a good one. Even "faith-healing" could be thought of as a "technology" applicable to the problem of rehabilitation.

It was assumed that although the state of society as reflected by the scenario variables strongly impacts upon the rehabilitation subsystem, the affect which the rehabilitation subsystem might have upon the scenario variables was negligible. In other words the policy-testing model is open-loop because its purpose is to test policy and not to predict the future course of rehabilitation. Thus feedback links which would connect the performance of the rehabilitation subsystem to rehabilitation policy have been deliberately severed in some models while weak feedback links were included in some GSIM models. In any case as the socioeconomic system evolves, the rehabilitation subsystem can become healthier and it is precisely such improvement that the models endeavor to assess under varying scenario and program thrust combinations.

In addition it is assumed (See Volume 3 for related assumptions) that the following statements are valid.

1. Egalitarianism and equity will continue to prevail.
2. Public funding for social welfare programs will continue.
3. Increased responsibilities must be concomitant with increased benefits.
4. Increased productivity is required to increase funding.
5. Government expenditures are financed by taxation.
6. Present goals of rehabilitation will continue:
    a) to infuse into the society and community,
    b) to assimilate into the workforce.
7. As technology increases rehabilitation techniques improve.
8. The rehabilitation problem is isolated from its sister problem, the problem of prevention.
9. The causality inherent within the rehabilitation subsystem is first of all deterministic and second of all separable [8,9].

Having stated the assumptions under which the models were formulated, the models themselves can be discussed.

GSIM Applications. The results of the GSIM applications are reported elsewhere -- See Volume 1, Chapter 6, and Volume 5. In this section, the applications are summarized and statements about the relative utility of using GSIM are made.

The work-sessions developed models that interrelated sets of variables identified in their consequence analysis efforts by means of a set of couplings or linkages giving a direction of influence and a relative magnitude. These "causal" models which are the result of the hierarchical and interrelationship analyses performed by the work-session participants summarize graphically the main causal statements made by the work-session participants. Some of the synthesized causal models are presented here in figures 1, 2, 3, 4, 5, 6, and 7 respectively.† The causal models were reformatted into their equivalent cross-impact matrix forms (See Appendix II) and these forms were then input to the computer in order to perceive the behavioral (dynamic) implications inherent within each causal model, using the GSIM algorithm.

The causal modeling and subsequent GSIM simulations served three important purposes:

1. They provided a powerful heuristic for use during the work-sessions in generating variables and interconnections relevant to the program thrusts.
2. Their pictorial appeal facilitated communication and stimulated cognition.
3. They collectively comprised a base of variables, parameters, and couplings to guide the development of more robust models.

The generic model was formulated by consolidating and aggregating the variables of the work-session models and by choosing the most general couplings obtained from the work-session reports. The consolidated variables are presented in table 1 and generic model is shown in figure 8.

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†Note: Verbal descriptions of these models are provided in Volume 5.

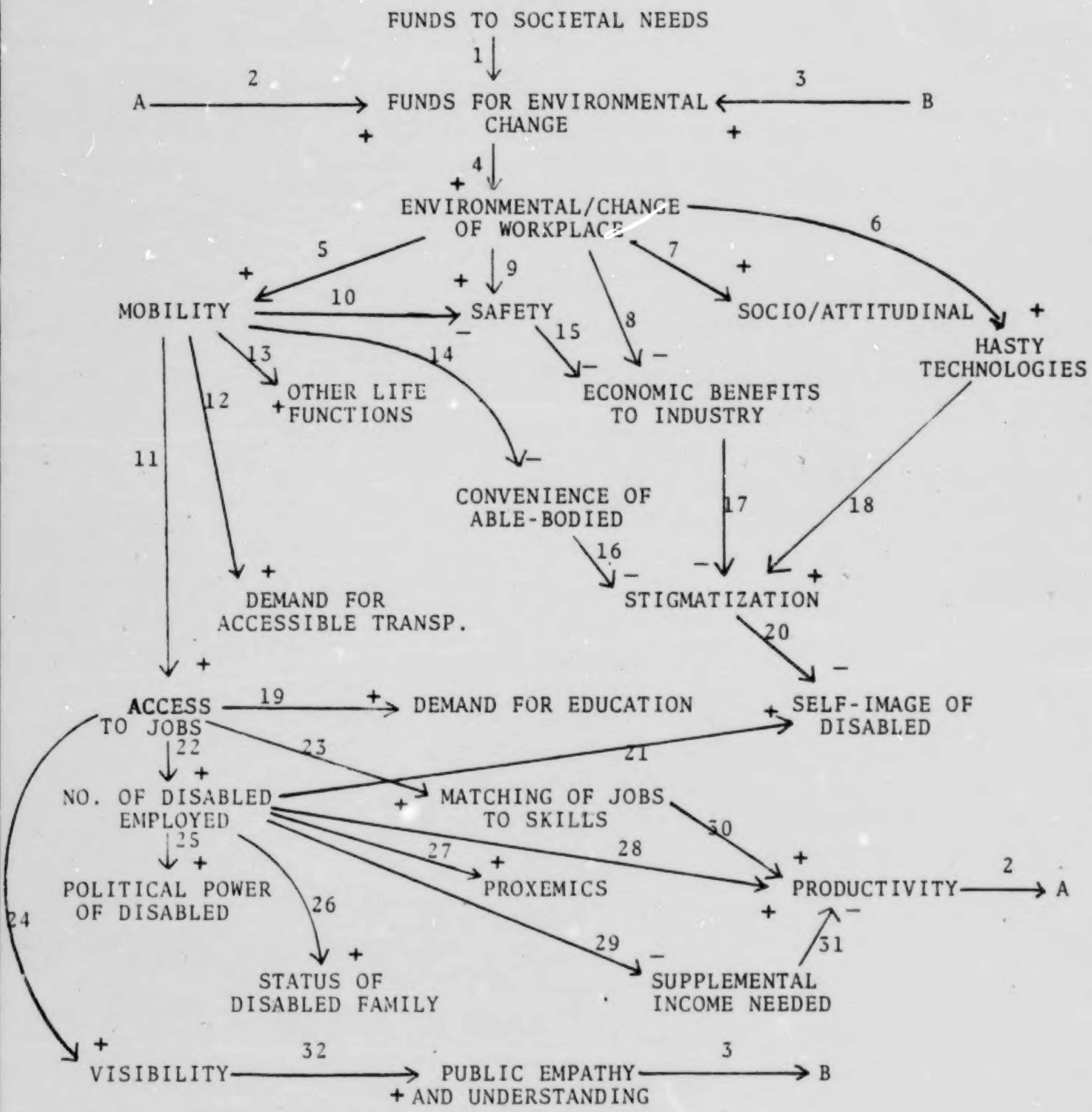


Figure 1. Hierarchical and interrelationship analysis of environmental change in the workplace program thrust

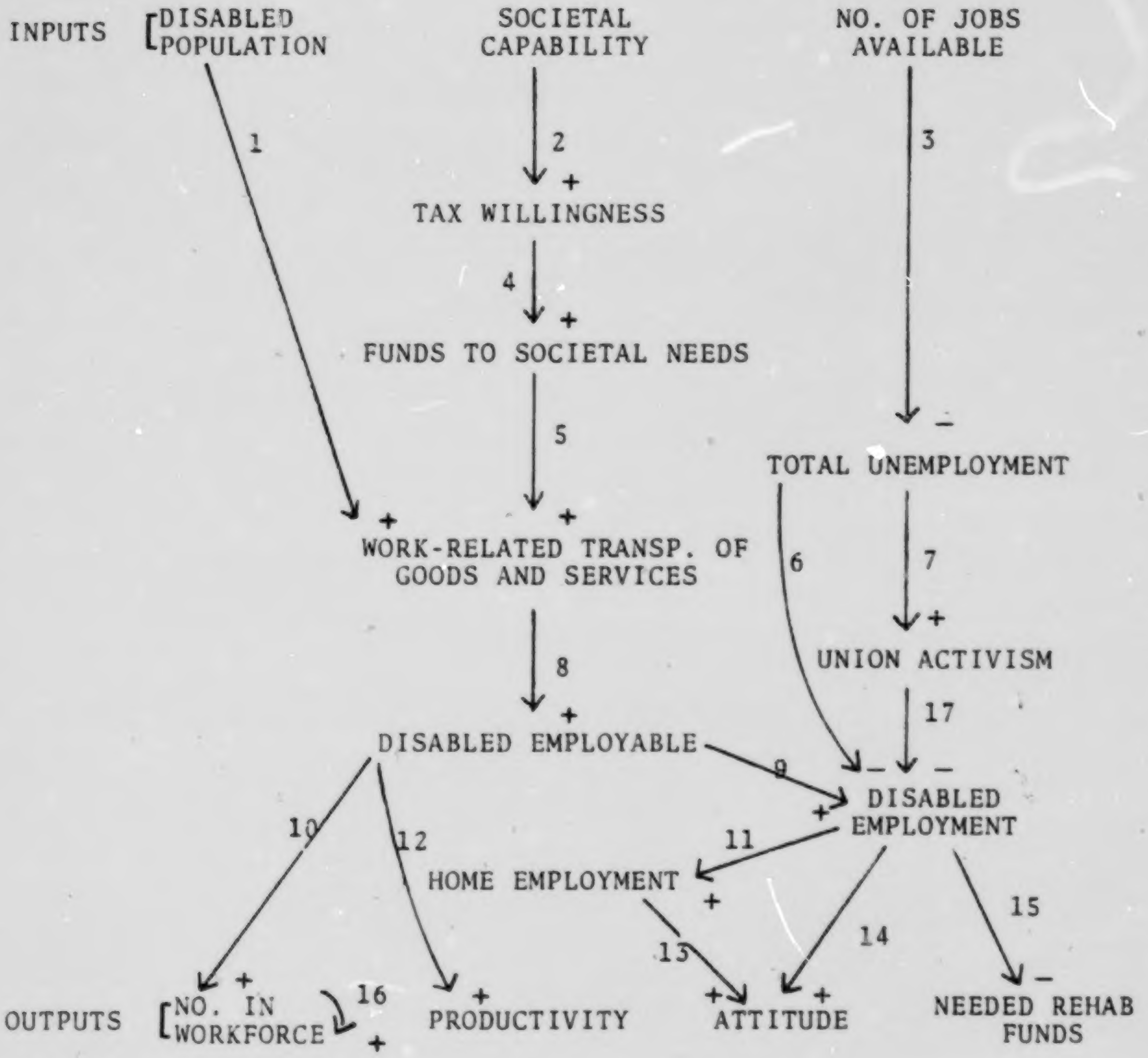
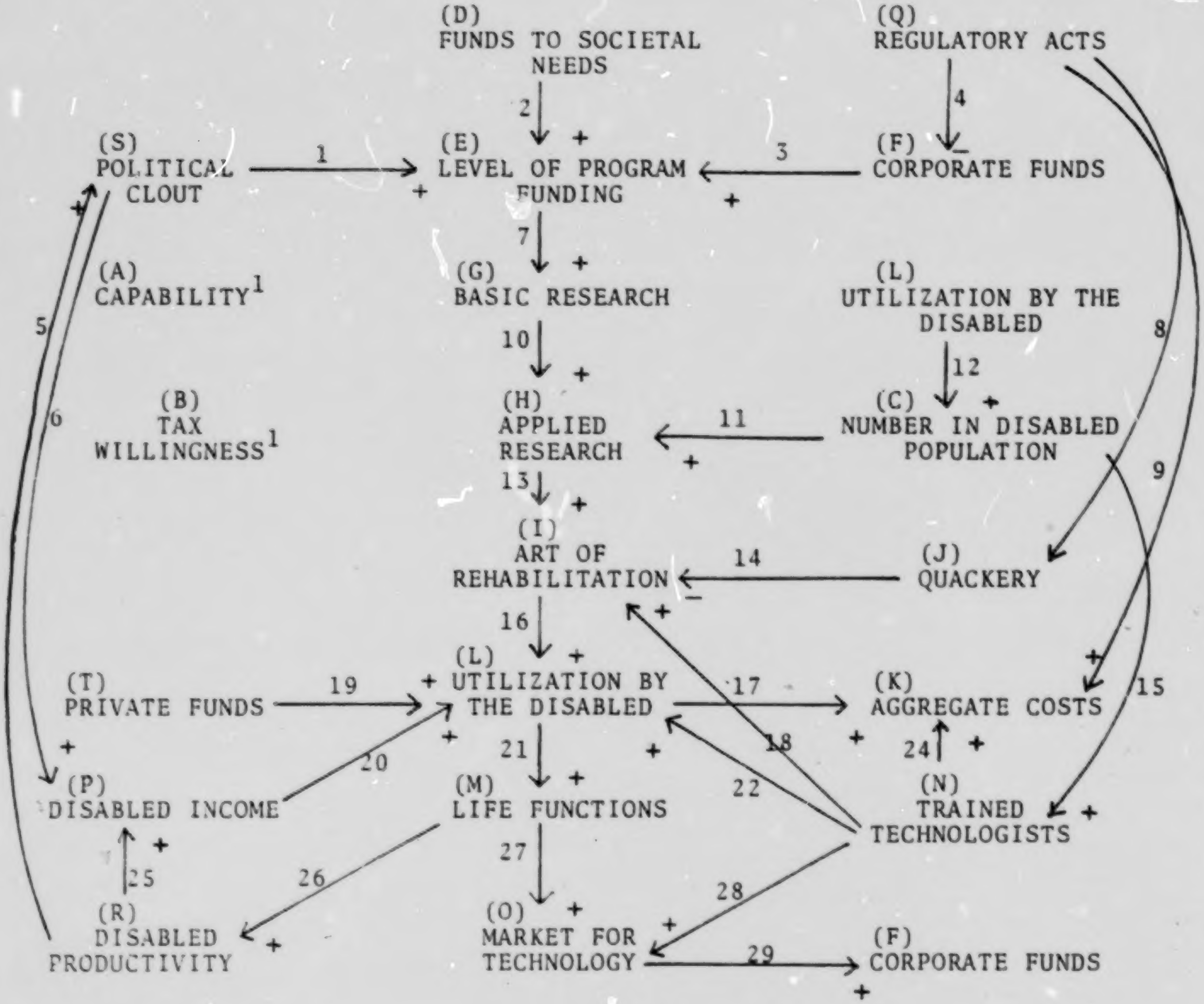


Figure 2. Causal diagram for the program thrust transportation of work-related goods and services



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[1] These variables were used for threshold evaluation only

Figure 3. Hierarchical and interrelationship analysis of physical intervention, physical therapeutic agents

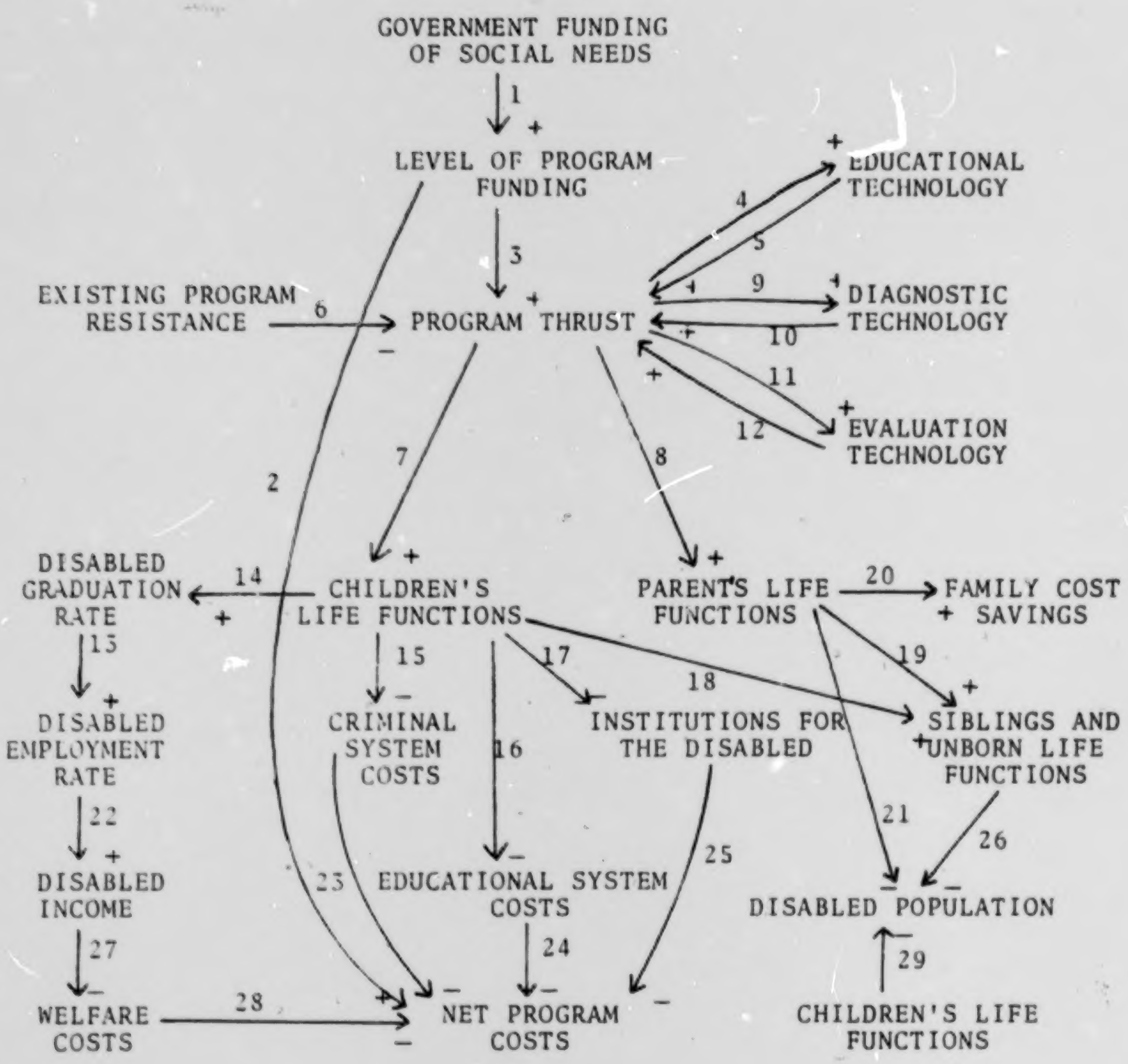


Figure 4. Causal diagram of hierarchical and interrelationship analysis of preschool academic education program thrust with emphasis on the economics of service delivery

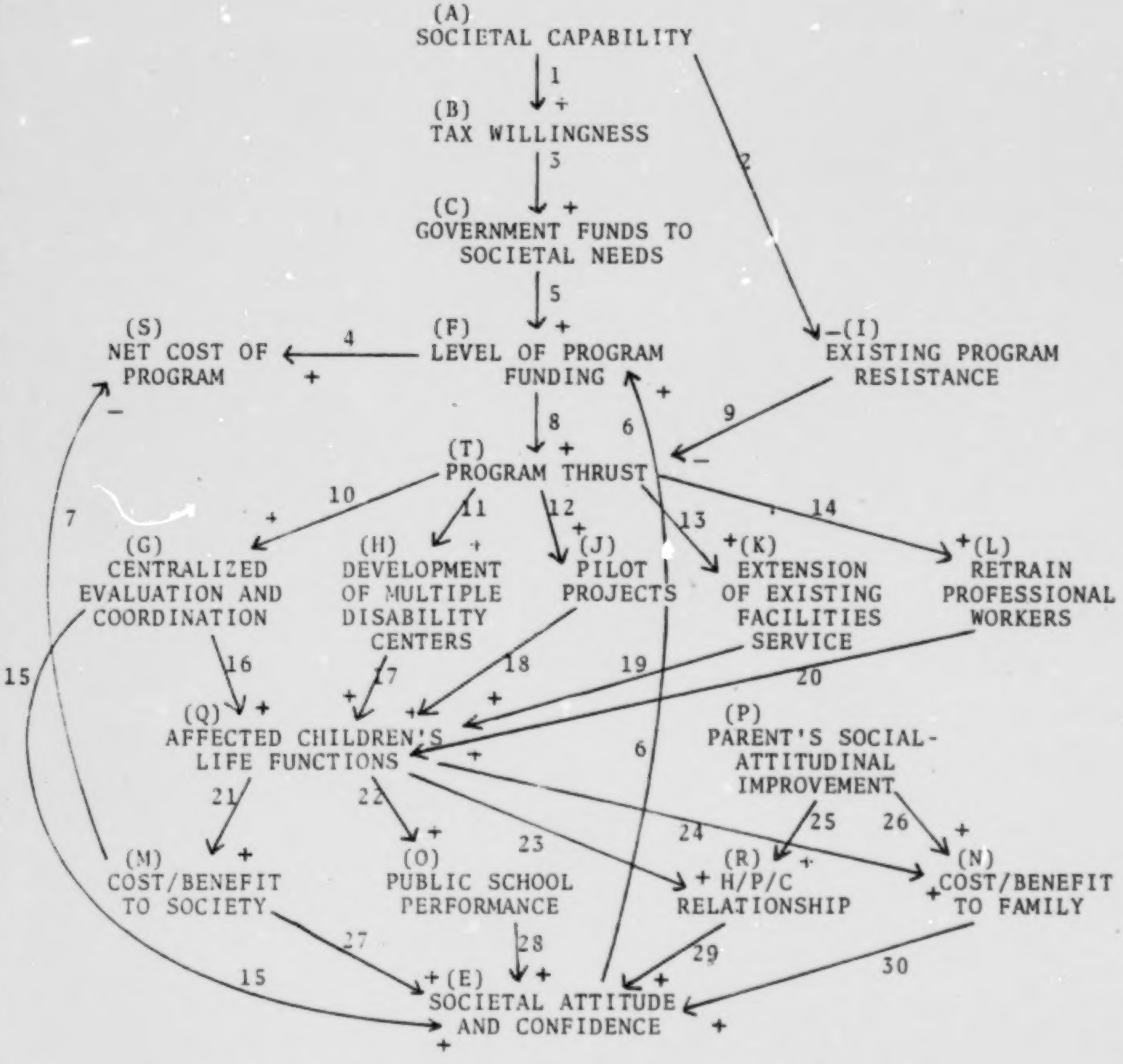

(A)
SOCIETAL CAPABILITY
1
+
2
(B)
TAX WILLINGNESS
3
+
(C)
GOVERNMENT FUNDS TO SOCIETAL NEEDS
5
+
(S)
NET COST OF PROGRAM
4
+
(F)
LEVEL OF PROGRAM FUNDING
+
–(I)
EXISTING PROGRAM RESISTANCE
–
7
8
6
9
(T)
PROGRAM THRUST
+
–
10
11
12
13
14
+
(G)
CENTRALIZED EVALUATION AND COORDINATION
(H)
DEVELOPMENT OF MULTIPLE DISABILITY CENTERS
(J)
PILOT PROJECTS
+(K)
EXTENSION OF EXISTING FACILITIES SERVICE
+(L)
RETRAIN PROFESSIONAL WORKERS
15
16
17
18
19
20
(Q)
AFFECTED CHILDREN'S LIFE FUNCTIONS
6
(P)
PARENT'S SOCIAL-ATTITUDINAL IMPROVEMENT
21
22
23
24
25
26
(M)
COST/BENEFIT TO SOCIETY
(O)
PUBLIC SCHOOL PERFORMANCE
(R)
H/P/C RELATIONSHIP
(N)
COST/BENEFIT TO FAMILY
27
28
29
30
15
(E)
SOCIETAL ATTITUDE AND CONFIDENCE
+

Figure 5. Causal diagram of hierarchical and interrelationship analysis for preschool academic education program with emphasis on logistics of service delivery

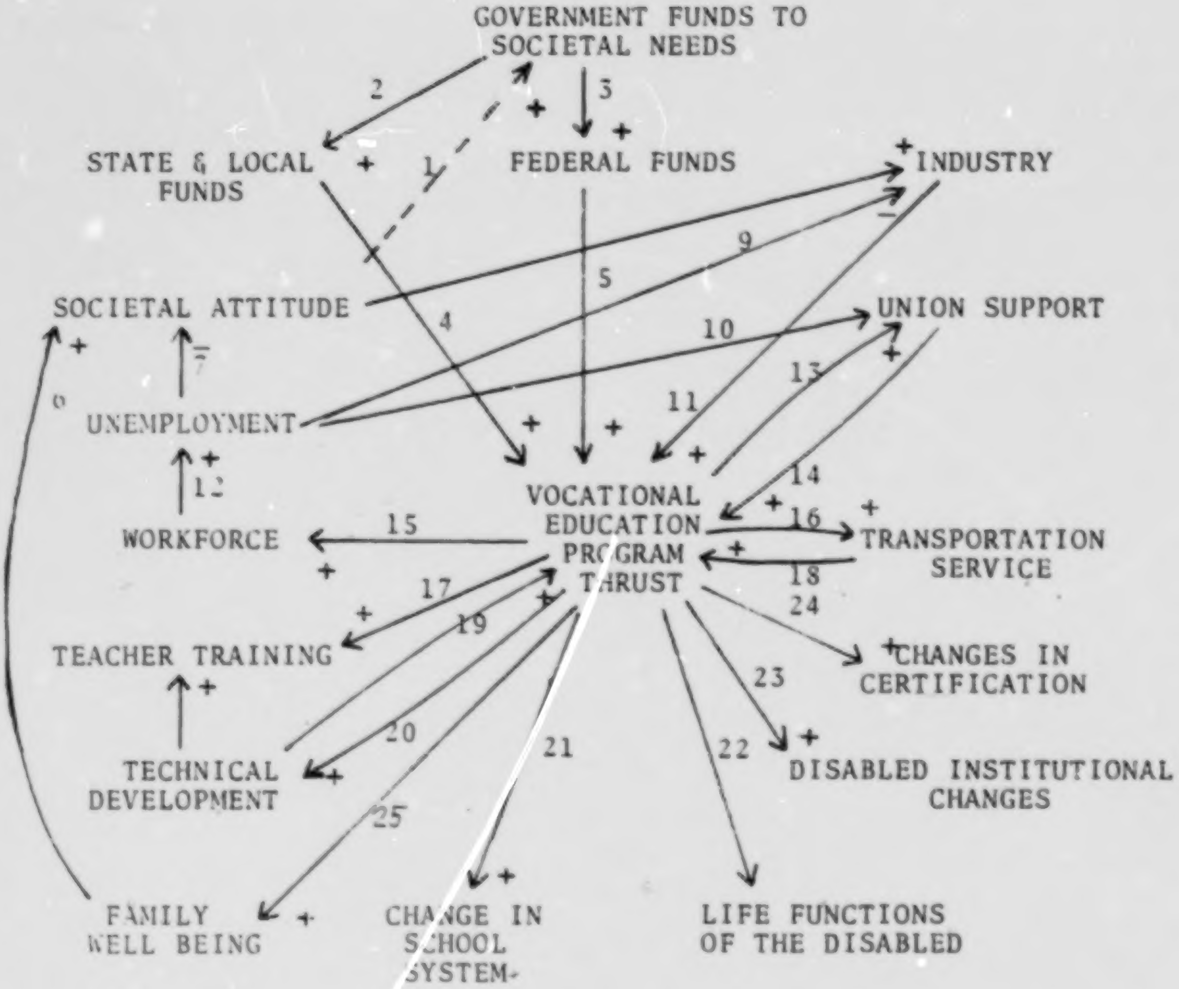


Figure 6. Causal diagram of hierarchical and interrelationship analysis of vocational education program thrust

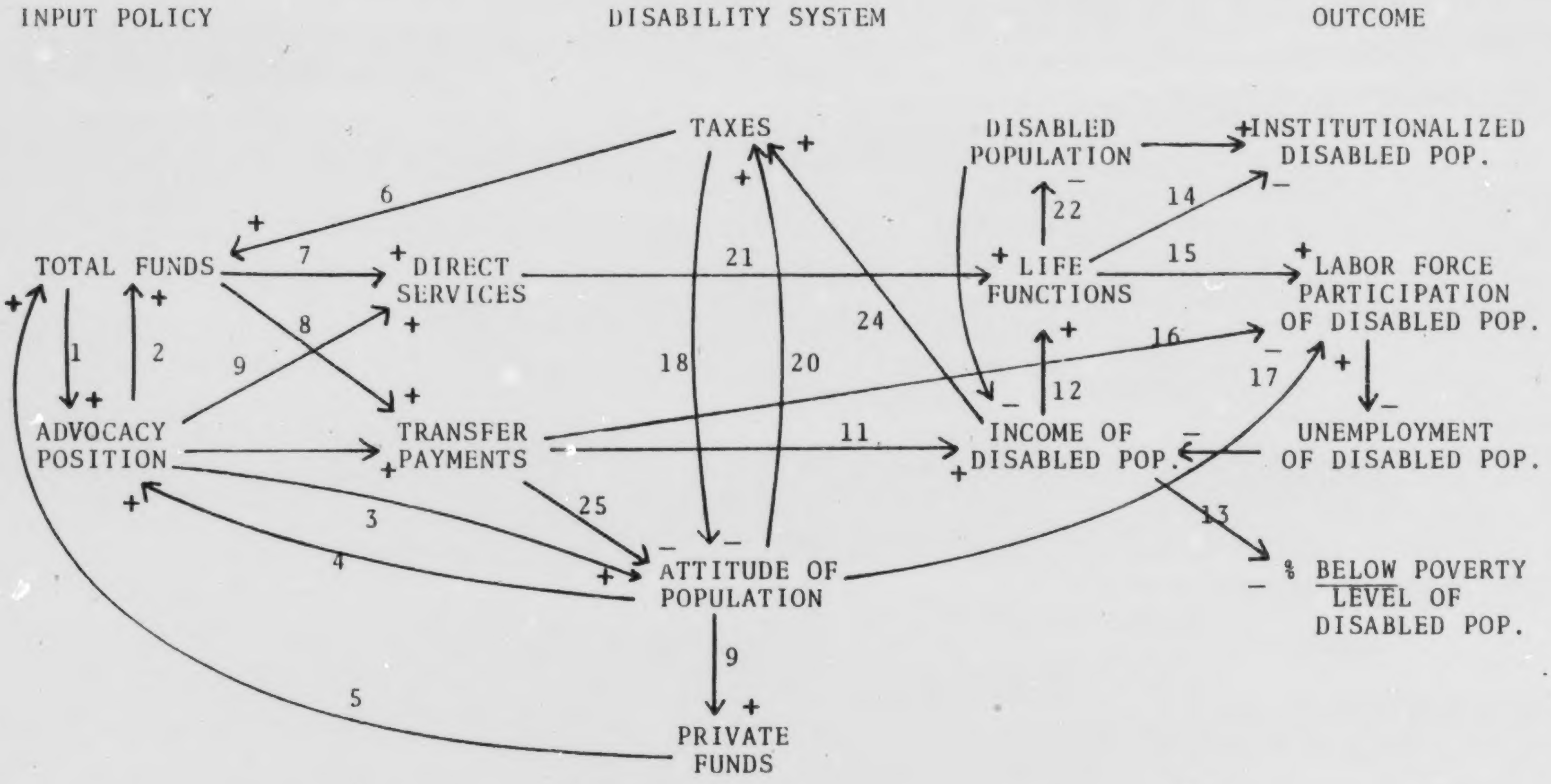


Figure 7. Hierarchical and interrelationship analysis of service delivery by advocacy

Table 1.

CONSOLIDATION AND GENERALIZATION OF VARIABLES AND PARAMETERS

Variable	Letter Designation
SCENARIO GROUP	
Societal Capability	A
Tax Willingness	B
Funds for Social Needs	C
Disabled Population	D
PROGRAM-THRUST GROUP	
Public Attitude	F
Level of Program Funding	E
Governmental	
Corporate	
Private	
Rehabilitation	L
Research	
Basic	
Applied	
Education and Training	
Disabled Persons	
Technologists	
Health-Care Professionals	
Services	
Medical	
Non-Medical	
Locus	
Management	
Administration	
Control	
Organization	
Locus	
Manpower	
Trained Technologists	
Health-Care Professionals	
Rehabilitation Technologies	
Market for Rehabilitation Technologies	
Resistance to Program Changes	
Quackery	
Utilization by the Disabled	
Facilities for the Disabled	I
Facilities for the Nondisabled	H

Table 1. (Continued)

Variable	Letter Designation
PROGRAM-THRUST GROUP	
Costs	J
Research	
Education	
Services	
Management	
Manpower	
Technology	
Family Costs	
Welfare System	
Criminal System	
Advocacy Position	G
Regulation	K
CONSEQUENCE GROUP	
Life Functions	O
Mobility	
Social-Attitudinal	
Communication	
Cognitive-Intellectual	
Health	
Status of the Disabled	N
Self-Image	
Visibility	
Community Integration	
Access to Jobs	
Employment	
Income	
Earned	
Supplemental	
Political Influence	
Education	
General	
Vocational	
Education Technology	
Demand	
Proxemics	
Status of Families with Disabled Member	P
Sibling Life Functions	
Parent Life Functions	
Total Labor Force	R
Total Employment	S
Total Jobs Available	Q
Economic Productivity	T
Disabled	
General Population	
Perceived Environment	M
Directly Related	
Incidentally Related	

NOTE: 'p' indicates a proportional coupling, 'a' indicates an accumulative coupling, and letters in parenthesis are used to simplify variable references in the causal diagram.

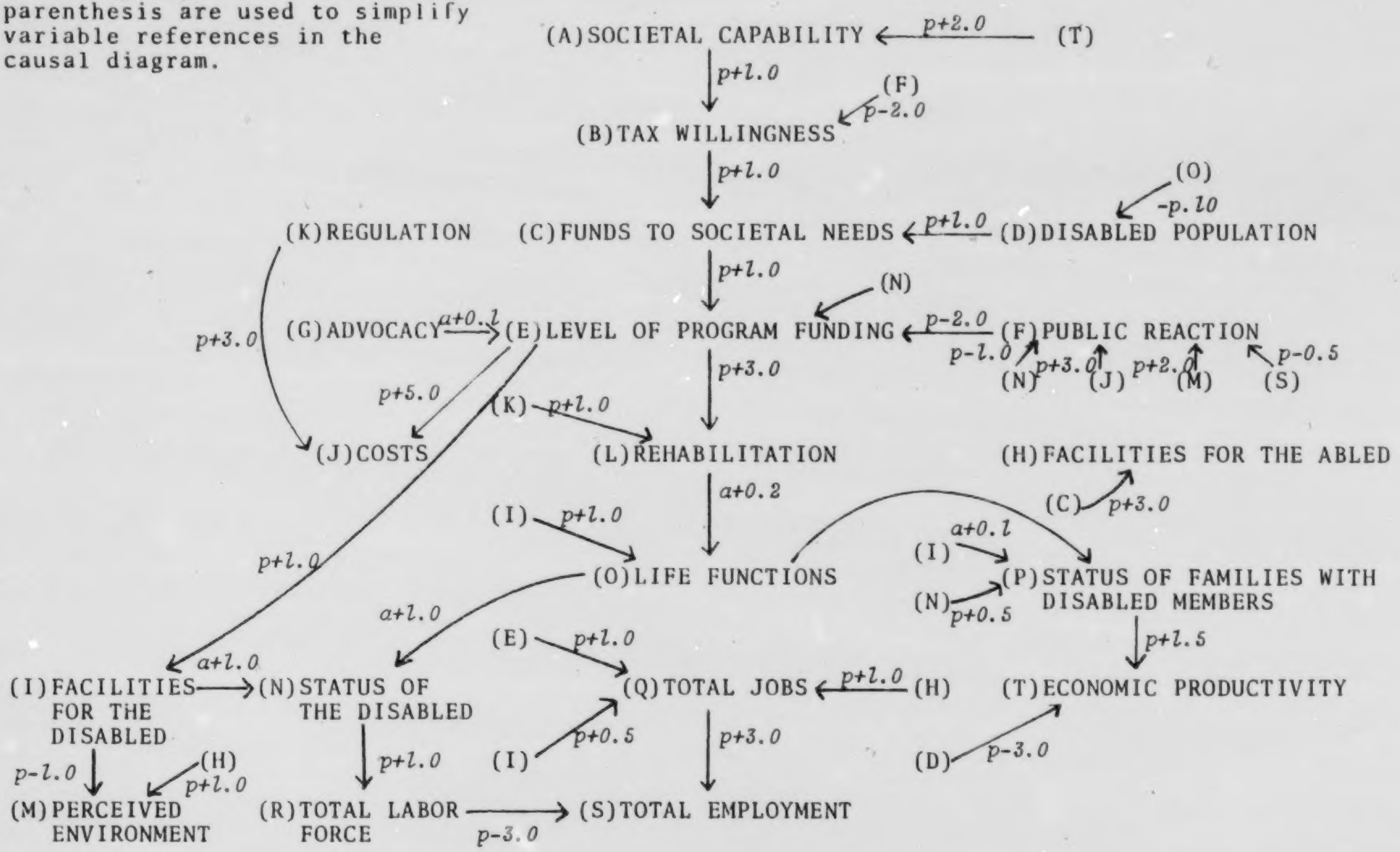


Figure 8. Causal diagram for the generic model

The generic model was formulated into a robust GSIM simulation (See Appendix I) including proportional couplings, accumulative couplings, thresholds, and input scenario data used to drive the models and to elucidate the sensitivity of consequence variables to scenarios. There were six cases evaluated using input projections for societal capability, societal willingness to be taxed, disabled population, and funds for social needs. The resulting dynamics allowed a rank ordering of variables by sensitivity to scenario. The significance of the generic model to the overall consequence analysis is as follows:

1. The generic model allowed the scenario variables, data, and causal statements to be aggregated to make general inferences about the significance of scenario changes upon human rehabilitation consequence variables.
2. The generic model allowed a rank ordering of consequence variables by sensitivity to scenario data for policy considerations. (See Volume I, chapter 6)

Results of GSIM Applications.

Typical of the results provided by the generic model are shown in figures 9, 10, 11, 12, 13, 14, 15, and 16. These figures show the affect of the various scenarios considered upon rehabilitation (Figure 9), perceived environment (Figure 10), status of the disabled (Figure 11), life functions (Figure 12), economic productivity (Figure 13), total jobs (Figure 14), total labor force (Figure 15), and employment (Figure 16). Figure 9 through 16 are discussed in Volume I,

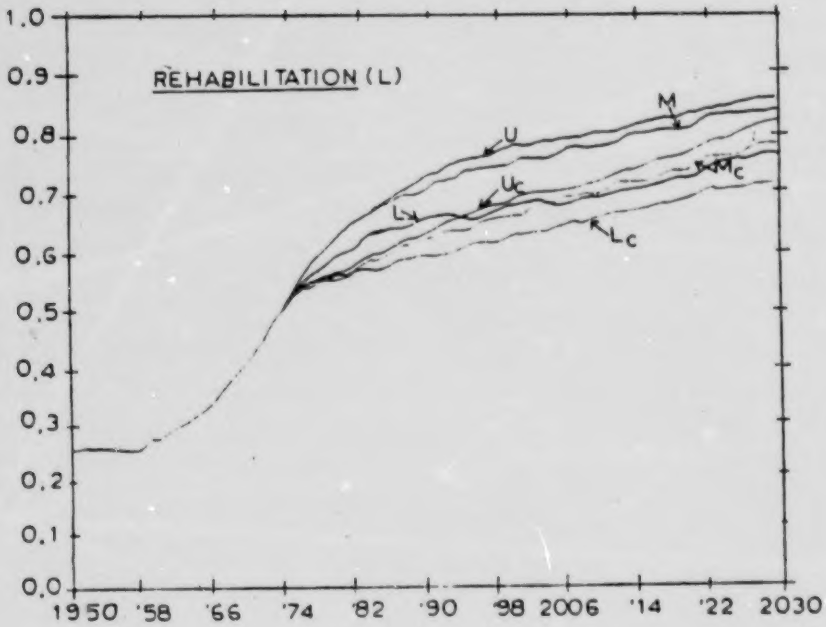


Figure 9. Rehabilitation (L)

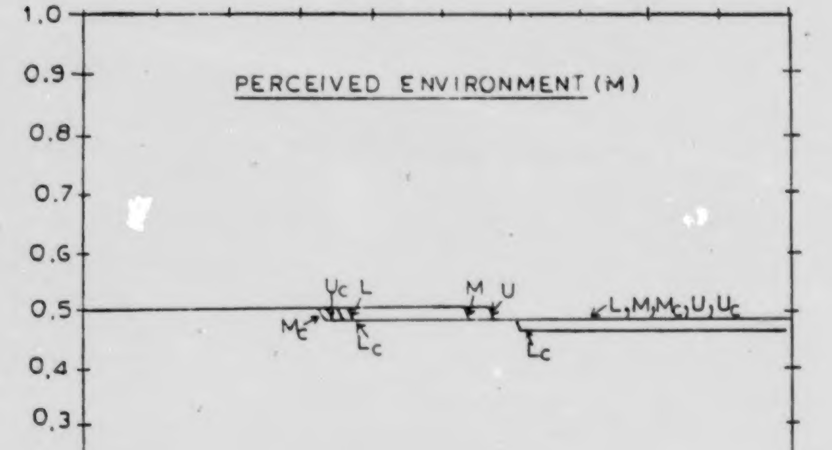


Figure 10. Perceived Environment (M)

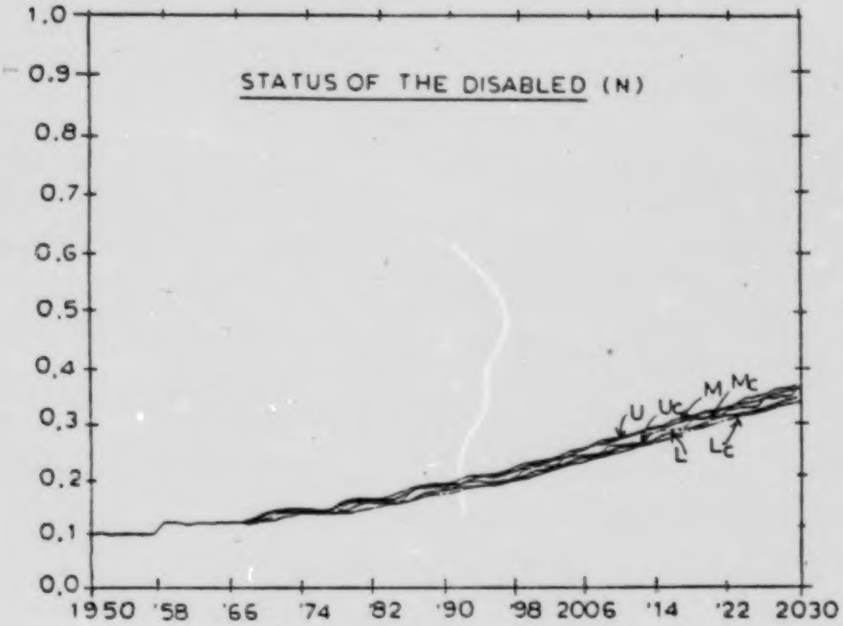


Figure 11. Status of the disabled (N)

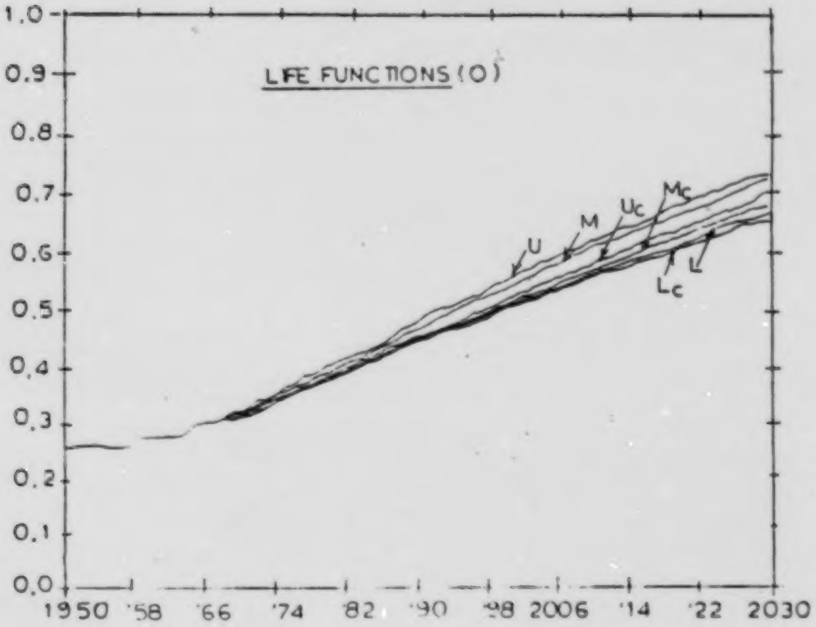


Figure 12. Life functions (O)

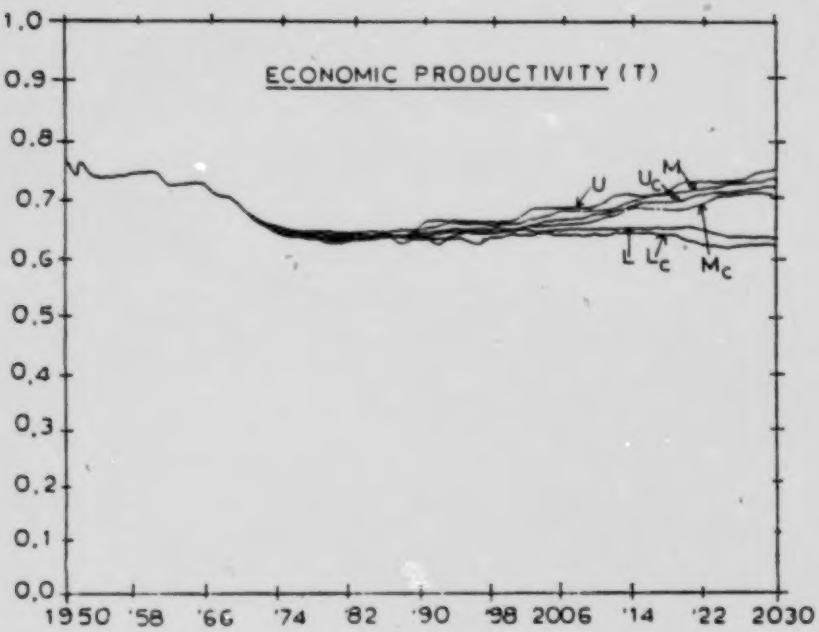


Figure 13. Economic productivity (T)

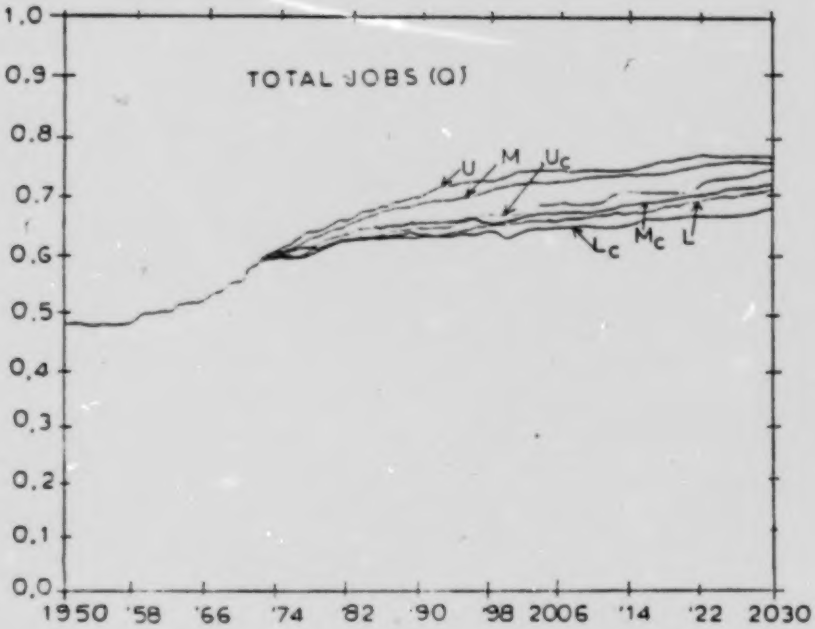


Figure 14. Total jobs (Q)

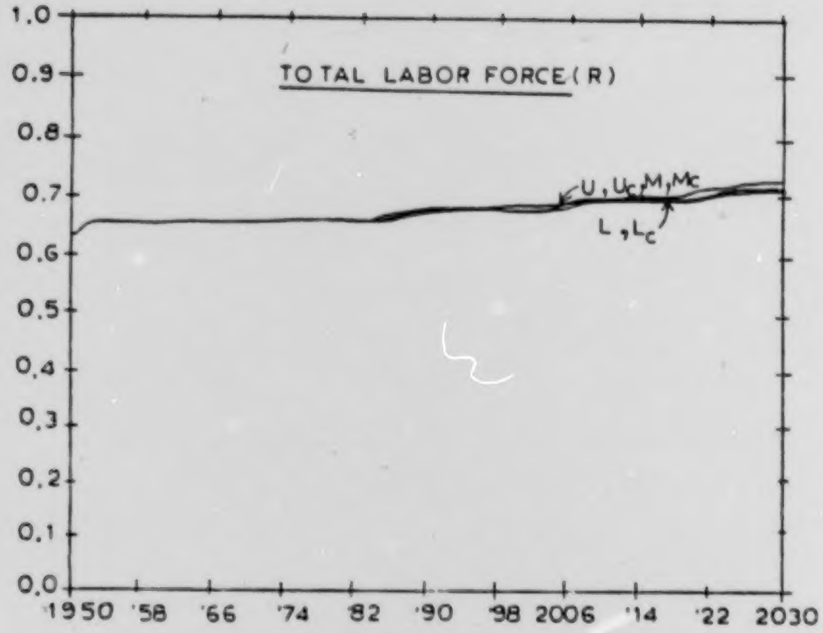


Figure 15. Total labor force (R)

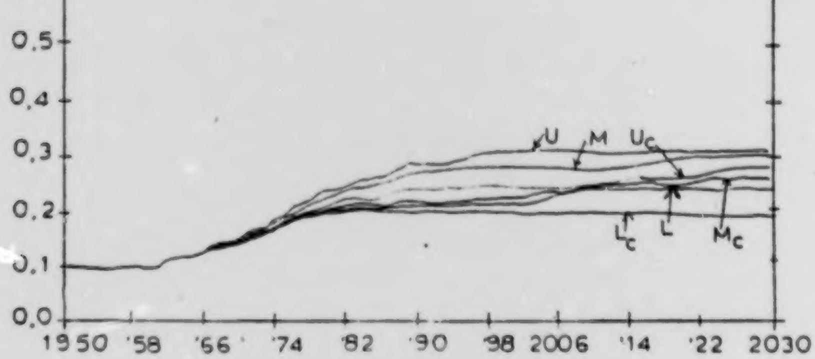


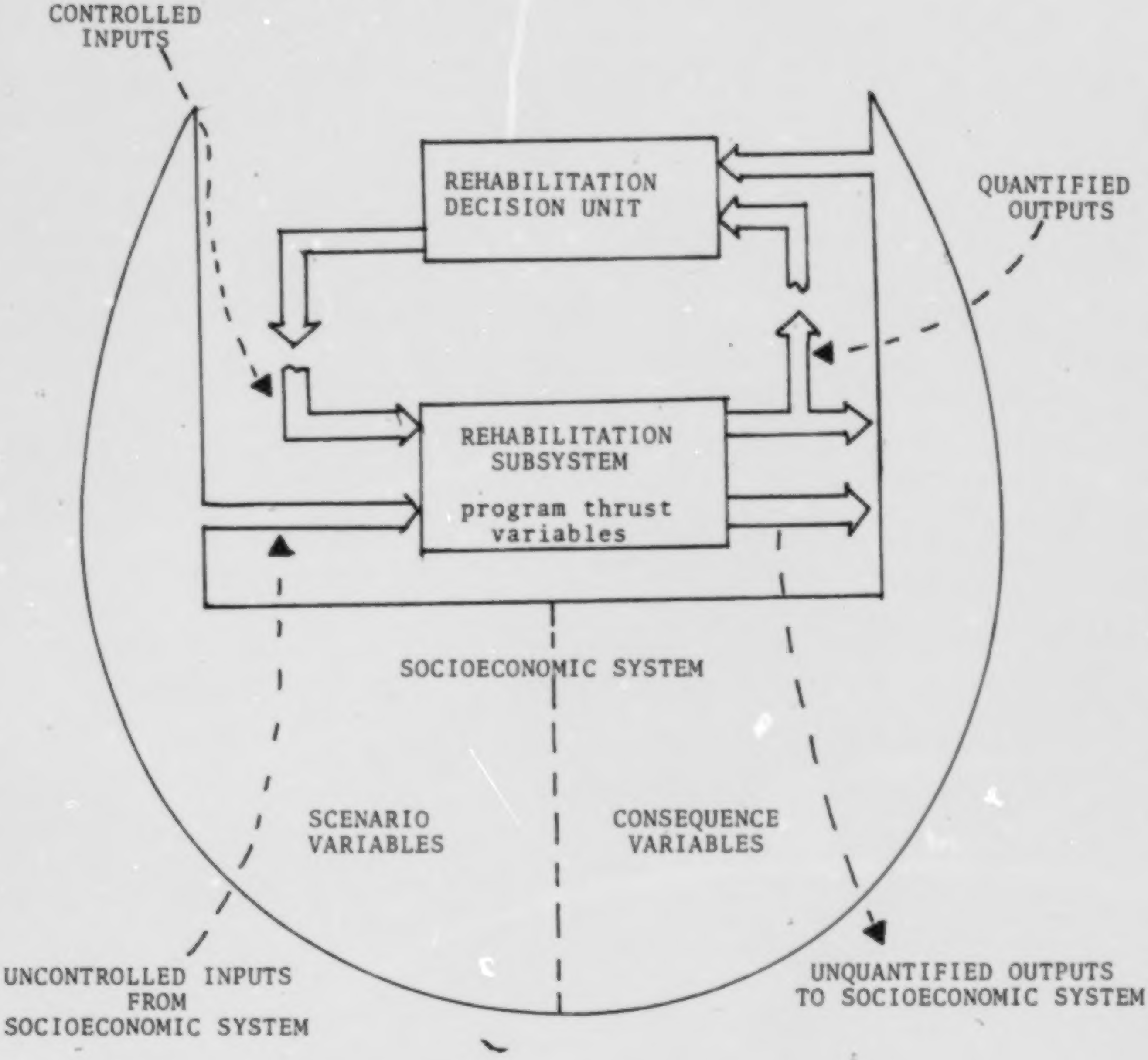
Figure 16. Employment (S)

Chapter 6. The designations U, U_c, M, M_c, L, and L_c are references to the upper, upper-constrained, medial, medial-contrained, lower, and lower-constrained driving scenarios respectively.

The Comprehensive Forrester Model.

The problem of rehabilitation (and the machinery required to alleviate it) has been treated as a subsystem embedded within the larger socioeconomic system as shown in the block-diagram model of Figure 17. The rehabilitation subsystem is driven by two classes of inputs -- inputs describing (by scenario) the existing socioeconomic environment within which rehabilitation must take place, and inputs describing the ensemble of programs and policies to be activated by the rehabilitation policymakers.

At the same time Figure 17 exhibits outputs or consequences which the rehabilitation subsystem transfers to the larger socioeconomic system. These outputs include such variables as disabled employed, disabled productivity, disabled income, disabled visibility, disabled status, etc.



Notes:
1) Uncontrolled inputs are specified by 'scenarios'
2) Controlled inputs represent 'policies'
3) Consequence analysis should indicate how the outputs will behave for each scenario and each policy alternative

Figure 17: A Block-Diagram Model of the Rehabilitation Subsystem

Within the rehabilitation subsystem are several smaller subsystems or sectors as previously mentioned. Included are a demographic sector, a technology and program thrust sector, a life-function sector, and a consequence sector. In addition, a scenario sector is also provided to generate the inputs from the larger social system. Although the scenario sector is not a part of the rehabilitation subsystem, it is required to "drive" the rehabilitation subsystem with time-varying societal inputs assembled into groups called "scenarios".

The five sectors interact with each other as shown in Figure 18 .

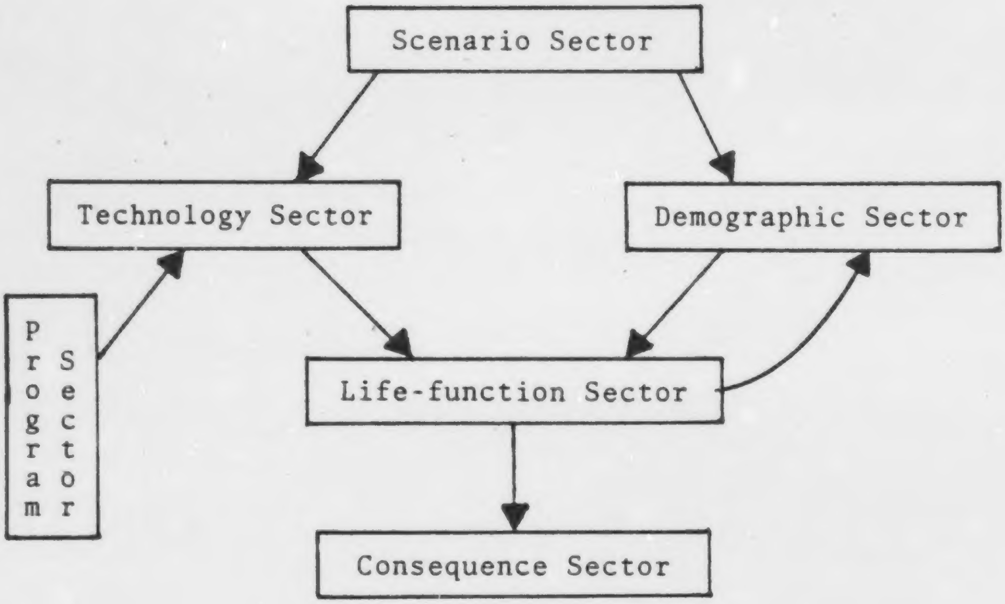


Figure 18: Interactions Among Sectors

The causal structure employed in each of the sectors was determined through a consideration of Forrester [3] concepts regarding flows and information transfers. In addition, the consequence sector structure was highly motivated by the generic GSIM model developed from the workshop sessions. The following sections provide a brief description of each of the sectors.

The Scenario Sector. This sector simulates the socioeconomic system in which the rehabilitation subsystem is embedded and consists of the quantities indicated in Table 2.

Table 2: List of Quantities in Scenario Sector

PLOT SYMBOL	NAME	VARIABLE	EQUIVALENCED VARIABLE
N	Net National Product	NNP	V(1)
C	Societal Capability	CAP	U(1)
1	Societal Willingness 1	SOC1	U(4)
2	Societal Willingness 2	SOC2	U(5)
W	Gov. Expenditures 1	GOV1	U(2)
I	Gov. Expenditures 2	GOV2	U(3)
R	Rehabilitation Funds	REF	W(2)
I	Employed Workforce	EMW	W(5)
G	Gross National Product	GNP	W(6)
S	Standard of Living	SOL	U(6)
S	Social Funds	SF	W(1)
•	Tax Rate	TR	W(3)
P	Productivity	PROD	W(4)
T	Technology Ratio	TR	V(4)
U	Unemployment	UNEM	V(5)

The scenario sector is strongly motivated by the scenario descriptions described elsewhere (See Chapter 5, Vol. 1, and Chapter 2, Vol. 4). The sector is set-up to "drive" the remaining sectors. Although "disabled population" and "total population" are obvious omissions to the list of scenario variables included in Table 2, these quantities are described in the demographic sector. Their dynamical behavior is nevertheless specified by scenario description.

There are four scenarios capable of being represented by the scenario sector. These are referred to as:

1) MEDIAL-M (moderate growth in funding for social concerns)
2) UPPER-U (accelerated growth in funding for social concerns)
3) LOWER-L (reduced growth in funding for social concerns)
4) ADFS (apocalyptic decline in funding for social concerns), which was introduced to make the scenarios encompass the full range of possible futures.

The causal structure employed by the sector is shown in Figure 19 below. Since this sector is intended to replicate the scenario descriptions found elsewhere, the causal structures employed for each scenario variable are somewhat disjoint from each other. Shown in Figure 19A are the structures employed for capability, net national product, and government expenditures. Shown in Figure 19B are the structures employed for societal willingness, and rehabilitation funds. Note that rehab funds is affected by societal willingness, societal capability, and disabled population. Depicted in Figure 19C are the structural descriptions for employed workforce, productivity, unemployment, gross national product, social funds, and standard of living. Depicted in Figure 19D are the causal descriptions for taxes, tax rate, and technology ratio.

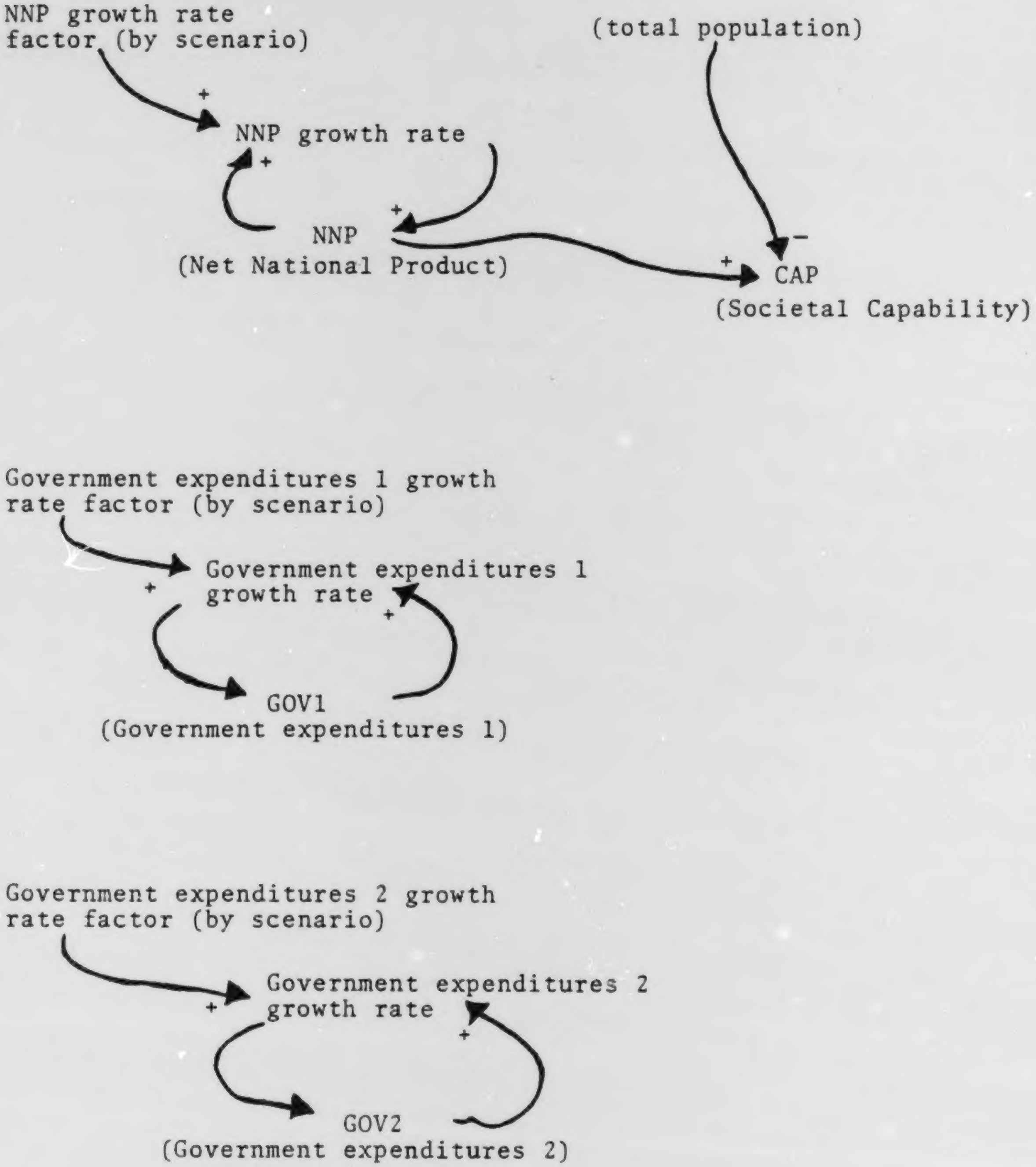

NNP growth rate factor (by scenario)
+
NNP growth rate
+
+
NNP
(Net National Product)
(total population)
−
+
CAP
(Societal Capability)
Government expenditures 1 growth rate factor (by scenario)
+
Government expenditures 1 growth rate
+
GOV1
(Government expenditures 1)
Government expenditures 2 growth rate factor (by scenario)
+
Government expenditures 2 growth rate
+
GOV2
(Government expenditures 2)

Figure 19A. (Part A) Causal Model of Scenario Sector

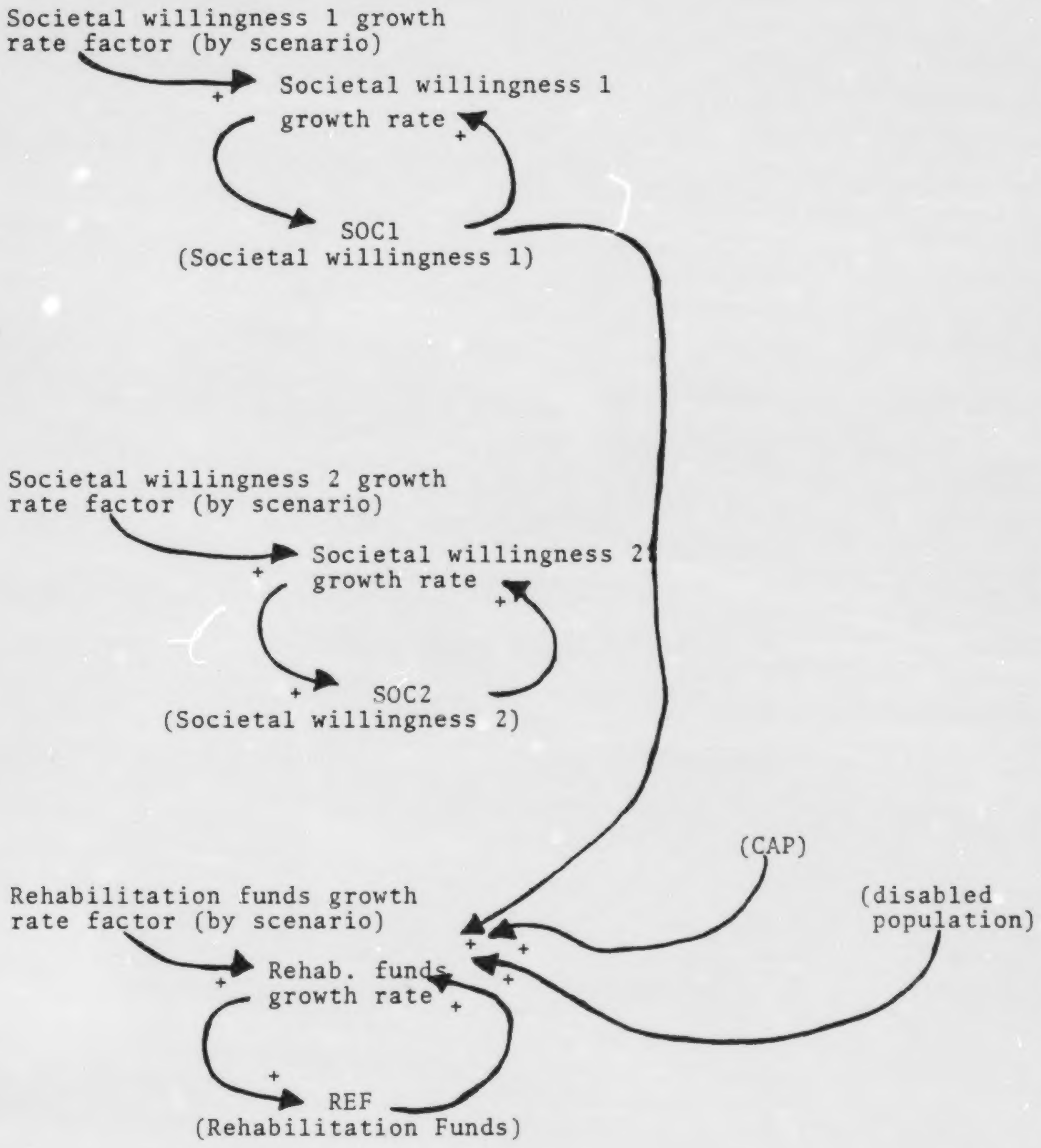

Societal willingness 1 growth rate factor (by scenario)
Societal willingness 1 growth rate
SOC1 (Societal willingness 1)
Societal willingness 2 growth rate factor (by scenario)
Societal willingness 2 growth rate
SOC2 (Societal willingness 2)
(CAP)
(disabled population)
Rehabilitation funds growth rate factor (by scenario)
Rehab. funds growth rate
REF (Rehabilitation Funds)
+
+
+
+
+
+
+
+
+
+
+
+

Figure 19B. (Part B) Causal Model of Scenario Sector

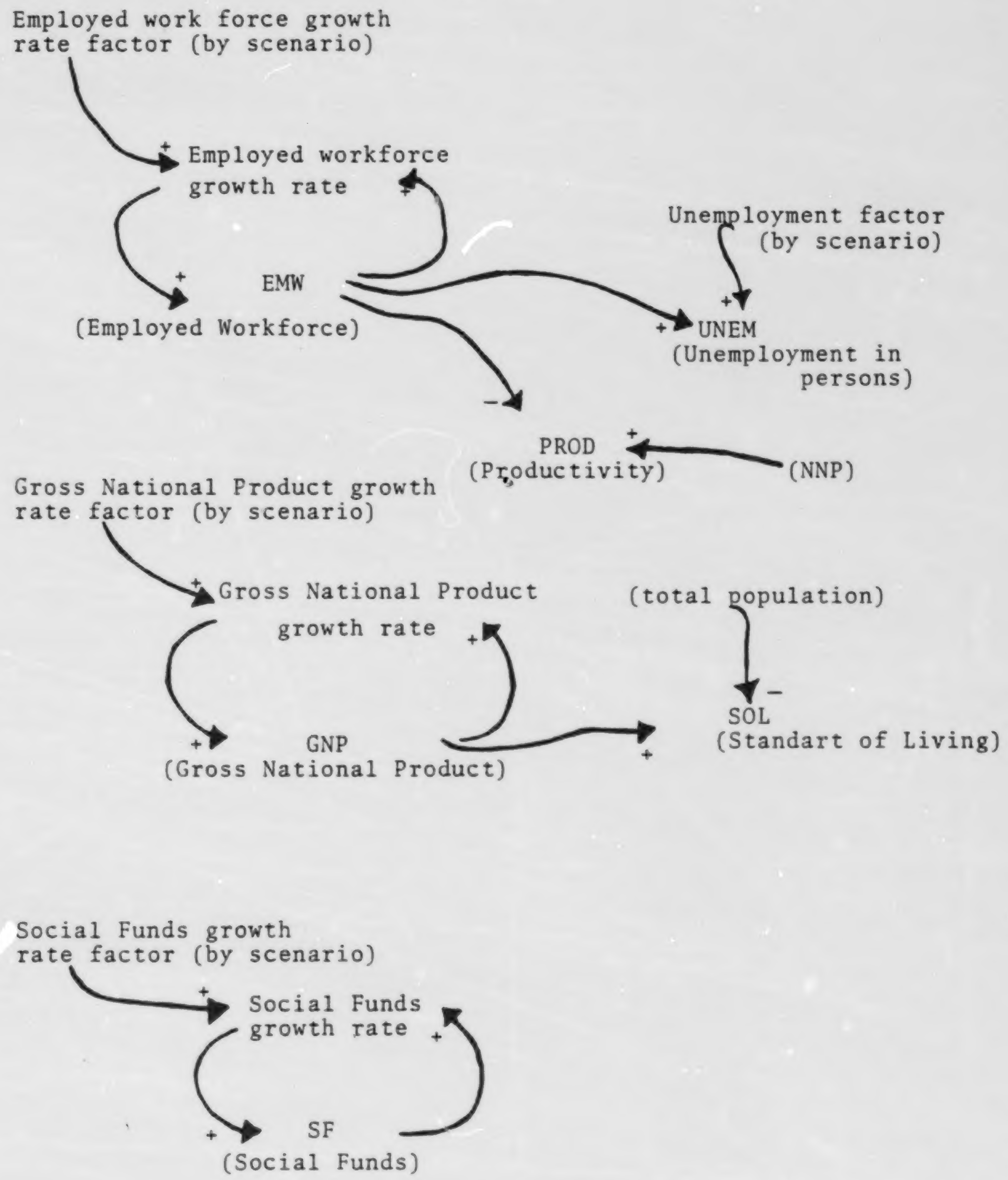

Employed work force growth rate factor (by scenario)
+
Employed workforce growth rate
+
+
EMW
(Employed Workforce)
Unemployment factor (by scenario)
+
+
UNEM
(Unemployment in persons)
–
PROD
(Productivity)
+
(NNP)
Gross National Product growth rate factor (by scenario)
+
Gross National Product growth rate
+
+
GNP
(Gross National Product)
(total population)
–
SOL
(Standart of Living)
+
Social Funds growth rate factor (by scenario)
+
Social Funds growth rate
+
+
SF
(Social Funds)

Figure 19C. (Part C) Causal Model of Scenario Sector

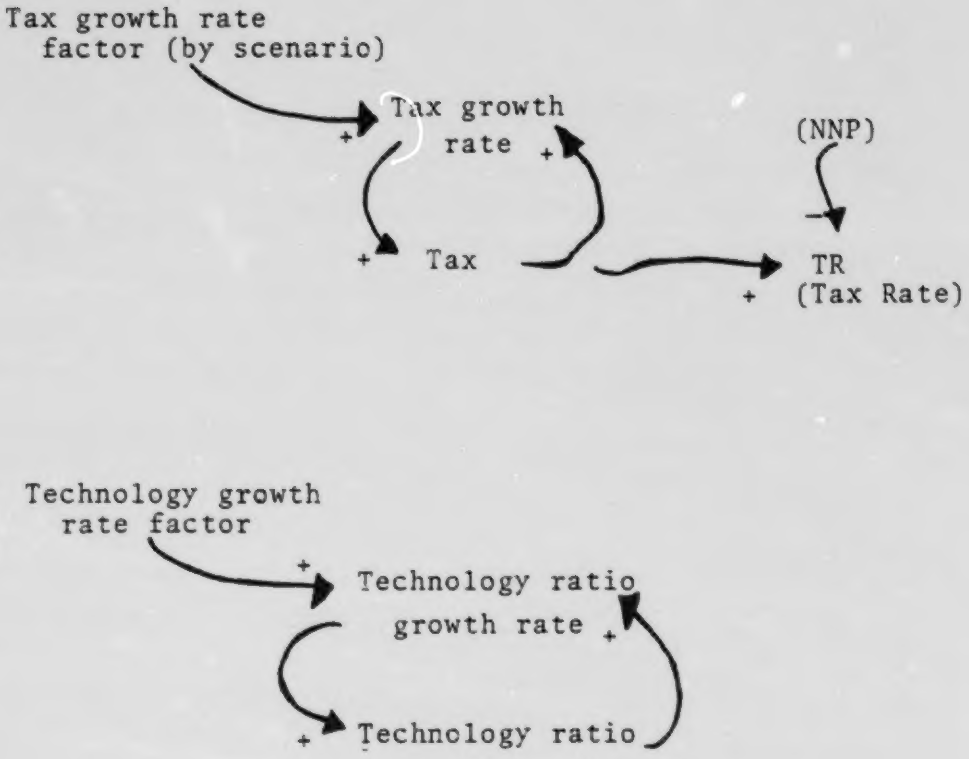
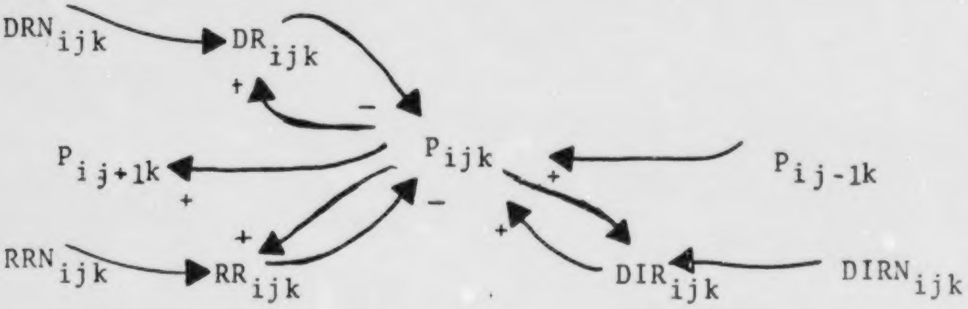

Tax growth rate factor (by scenario)
+
Tax growth rate
+
+
Tax
(NNP)
−
TR (Tax Rate)
+
Technology growth rate factor
+
Technology ratio growth rate
+
+
Technology ratio

Figure 19D. (Part D) Causal Model of Scenario Sector

The Population Sector. The population sector consists of abled and disabled population categories broken down by age and sex into "cohorts". There are, specifically, 14 case-study disabilities, a disabled population, and a total population in the model. Age increments of five years are used for ages 0 through 64, with the last age-type including all persons within a particular disability and sex category that are over 64. Each sex, age, and disability category employs, generally, the following causal structure. There are, however, many exceptions to the causal structure depicted below that are used in the population sector.



where P_{ijk}, P_{ij+1k}, P_{ij-1k} } disabled population categories

i = index on disability
j = index on age
k = index on sex

DR_{ijk} − death rate
RR_{ijk} − rehabilitation rate
DIR_{ijk} − disabling rate

Figure 20 : Causal Diagram for a "typical" Age, Sex, and Disability Cohort

Each such cohort possesses its own differential equation. There are 420 such cohorts when 15 population categories, 14 age groups and 2 sex groups are considered. A typical differential equation for one such cohort is

$$\dot{P}_{ijk} = \frac{dP_{ijk}}{dt} = DIR_{ijk} - DR_{ijk} - RR_{ijk} + (P_{ij-1k} - P_{ij+1k})/5. \quad \Big| \quad P_{ijk}(t_o) = P_{ijk_o}$$

where each of the terms are defined in Figure 20 above. Distinctly different differential equations and causal diagram representations are necessary for some cohorts -- i.e., age 0-5, age 65+, the nondisabled population cohorts, etc.

The cohort strategy employed here was motivated by early discussions with individuals involved in the study. The structure has been tested and shown to be workable (see results). However, there is some problem in getting the necessary data. Specifically, accurate determination of the number of individuals within each disability category is required. Then the birth rate for each disability group, the frequency of incidence or occurrence of each disability broken down by age and sex, and the rate of rehabilitation of each disability group also broken down by age and sex is required. This information would be used to establish the rates DIR_{ijk}, RR_{ijk} in Figure 20 above. In addition information about death rates also broken down by age, sex, and disability would be required to establish DR_{ijk} in Figure 20 above. Such information is not readily available, but for some disabilities can be extracted from related data.

In addition to the age, sex, disability breakdown, it would also be of interest if severity considerations could be incorporated. Three levels of severity could increase the number of differential equations by three, depending upon how it is implemented.

The demographic sector, as currently structured, rehabilitates the disabled population back into the healthy population. This is in contradistinction to rehabilitation into a disabled-rehabilitated category as previously discussed. At the same time frequencies of disability incidence or occurrence are applied only to the healthy population. The possibility for multiple disabilities is accounted for by allowing a disabled person afflicted with more than one disability to be counted in more than one disability group. The population categories treated in this sector are exhibited in Table 3 below.

Inputs to the demographic sector are all demographic incidence parameters, including

DRN_{ijk} Death rate normal for cohort ijk,

$DIRN_{ijk}$ Disabling incidence rate normal for cohort ijk,

BRN_{i} Birth rate normal for disability group i,

RRN_{ijk} Rehabilitation rate normal for cohort ijk.

Of the four above-listed quantities, all are assumed constant for the duration of the simulation, except RRN_{ijk}. RRN_{ijk} is functionally dependent upon the technology, life function, and program sectors. Inputs from these sectors could be used to specify RRN_{ijk}. However, the data necessary for such specification is unavailable. In general, it is not known how efficacious or expensive it is to use a particular program (technology) or program thrust (an ensemble of harmonious programs) to accomplish the task of rehabilitation for a particular disability group. For example, it is not known how many more disabled persons were employable as a result of environmental change programs in the workplace even though there are some two million ambulatory disabled persons in the country toward which the program is directed. However, there must also be jobs for these persons, and these persons must have training (skills) necessary to perform the task descriptions within each vacant job. Finally, these persons must have transportation to the jobs. Efficacy data are unavailable for nearly every other program or technology considered. Consequently, data for RRN_{ijk} was conjectured to illustrate the manner in which the sector would work if the data were available.

By way of outputs to other sectors, the sector computes and transmits the total population in each group by way of the array $PTOT_i$ defined in Table 3. Other outputs include RRT_i and ART_i, the total persons rehabilitated and becoming disabled respectively for disabled category i. These are used in the life function sector and elsewhere.

Table 3: List of Population Groups in Demographic Sector

Plot Symbol	Description	Variable Names
R	Rheumatoid Arthritis	PTOT (1)
C	Coronary Heart Disease	PTOT (2)
E	Emphysema	PTOT (3)
O	Colon/Rectum Cancer	PTOT (4)
K	Kidney Disease	PTOT (5)
D	Diabetes Mellitus	PTOT (6)
S	Schizophrenia	PTOT (7)
M	Mental Retardation	PTOT (8)
P	Epilepsy	PTOT (9)
B	Cerebral Palsey	PTOT (10)
T	Stroke	PTOT (11)
A	Spinal Chord Injury	PTOT (12)
V	Visual Impairments	PTOT (13)
H	Hearing Impairments	PTOT (14)
N,P	Total Population	PTOT (15), V(2)
D	Total Disabled Population	V(3)
E	Rehabilitation Funds per Disabled Person	V(6)

The plots for the demographic sector are depicted on pages 84-95 with adjacent discussion found on pages 81-83.

The Technology Sector. This sector is intended to "transform" dollars spent for rehabilitation into life function improvement. As such the sector is really a subsector of the life function sector. The sector contains data on which technologies affect which life functions within each disability group. The sector could also, to a limited extent, express the degree of life function improvement which accrues from the allocation of a certain level of funding to a specific technology.

In this sector data on which technologies affect which life functions within a particular program thrust area was assembled from data provided in Project Paper No. 4, Volume 4, using the computer. The results of such data manipulation are provided in the sub-section on results.

There are five major quantities (See Table 4) in the technology sector which interact as shown in Figure 21. Of these five major quantities, only DLFIN and PTOT are variables -- the remaining quantities are inputs (constants). Clearly, DLFIN is functionally dependent upon COSTPC, PTOT, TECHNO, and APPDOL. The exact relation is the following dimensionally consistent equation:

$$\mathrm{DLFIN}_{n,i} = \mathrm{DLFIN}_{n,i} + \frac{(\mathrm{TECHNO}_{n,i,m} \cdot \mathrm{APPDOL}_{n,i,m})}{(\mathrm{COSTPC}_{i,m} \cdot \mathrm{PTOT}_{i})} \quad . \qquad (1)$$

Since there are five life functions and 14 disability groups, there are $5 \cdot 14 = 70$ equations of this type.

From Figure 21, one should infer that no level or state equations are to be found in the technology sector. Thus the current state of the rehabilitation technology is assumed to

Table 4: Major Quantities in Technology Sector

$TECHNO_{n,i,m}$	A transfer function expressing the degree of improvement upon life function n due to supplying technology m to one person in disability group i
$APPDOL_{n,i,m}$	The dollars allocated for improvement of life function n through funding technology m to persons in disability group i (on a per annum basis)
$COSTPC_{i,m}$	The cost to supply technology m to one individual in disability group i (on a per annum basis)
$PTOT_i$	The number of persons in disability group i
$DLFIN_{n,i}$	The change in life function n within disability group i

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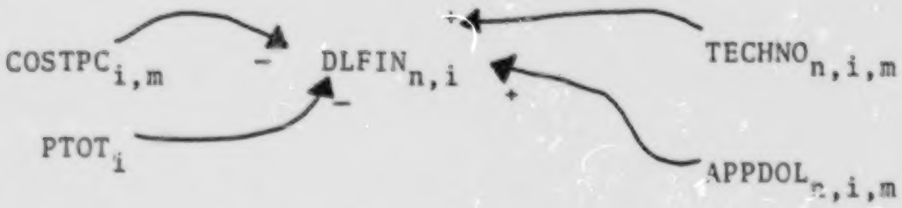

Figure 21: Major Interactions Within Technology Sector

remain relatively constant. The sector does not, therefore, reflect the affects on rehabilitation technology of funds spent for technological research and development in rehabilitation. Again, due to the absence of data no one knows how much gain in rehabilitation (as measured by life function improvement) will accrue from the allocation of a certain level of funds to research, making a funding-driven, technologically dynamic structure impossible to characterize.

What the structure in Figure 21 does reflect is the *relative* change in each life-function which would result from allocating a certain amount of funds APPDOL to the *application* of a certain technology m to a certain disability type i, given the cost COSTPC on a per-annum per-person basis, and the total number of persons in the disability group.

The Life Functions Sector. In this sector each of the five life functions (mobility, health, communication, cognitive-intellectual, and social-attitudinal) are quantified and indexed by disability. Each disability population $PTOT_i$ has an associated set of five life function measures $LF_{i,d}$. Each measure is allowed to vary in the range 0 to 1 where 1 represents normal or average functioning within a particular life function area. The measures $LF_{i,d}$ are aggregated to produce overall measures given by ALF_i. There are 70 (14 disability populations times 5 life function measures) states and differential equations in this sector, and 5 auxiliary variables.

The major quantities included within the life-function sector are those listed in Table 5. The interactions assumed for the sector are those shown in Figure 22. Here $LIFEFN_{n,i}$ is a state or level variable dependent upon

1) changes in life functions caused by the application of technologies $DLFIN_{n,i}$
2) changes in life functions caused by entrances and and exits associated with disability group i.

There are, in addition to Equation (1) prescribing the life function changes due to technologies, two major equations in the life functions sector. They are:

$$DLFNET_{n,i} = ((1.-LIFEFN_{n,i}) \cdot RRT_i - LFAR_{n,i} \cdot ART_i)/PTOT_i \quad (2)$$

$$\dot{LIFEFN}_{n,i} = (DLFIN_{n,i} - DLFNET_{n,i}) \cdot (-LIFEFN_{n,i} \cdot \ln(LIFEFN_{n,i})) \quad (3)$$

$$LIFEFN_{n,i}(t_o) = LIFEFN_{n,i_o}$$

Here $\dot{LIFEFN}_{n,i}$ represents the time rate of change of $LIFEFN_{n,i}$.

TABLE 5: Major Quantities Included within Life-Function Sector

$DLFNET_{n,i}$	The net change in life-function n within disabled group i due to the flux of individuals leaving and entering the respective disabled group.
$LIFEFN_{n,i}$	The state or level variable representing each life-function for each disability group.
RRT_i	Total persons rehabilitated within disability group i on a per-annum basis.
$LFAR_{n,i}$	Average life-function index n for persons entering disabled group i.
ART_i	Total persons entering disabled group i on a per-annum basis.
$PTOT_i$	Total persons in disabled group i.
$DLFIN_{n,i}$	The input from the technology sector.

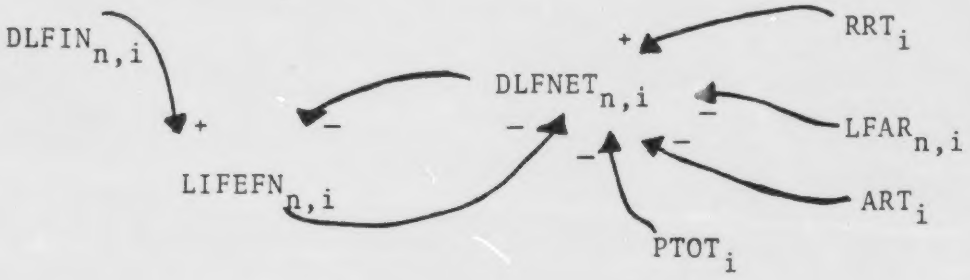

Figure 22: Major Interactions within Life-Function Sector

It should be apparent that a sigmoid model is employed for each of the (5 x 14) 70 life function indices. The sigmoid behavior is due to the modulation function $(-\text{LIFEFN}_{n,i} \cdot \ln(\text{LIFEFN}_{n,i}))$ attached to Equation (3) -- see Appendix II.

Aggregates of all five life functions are plotted. Table 6 is a list of the variable names and plot symbols used.

Table 6: List of Quantities that are Plotted in the Life Function Sector

Plot Symbol	Description	Variable Name
H	Health	ALF(1)
S	Social-Attitudinal	ALF(2)
M	Mobility	ALF(3)
C	Cognitive-Intellectual	ALF(4)
O	Communication	ALF(5)

In addition to $\text{DLFIN}_{n,i}$, the input from the technology sector, the remaining inputs to this sector are $\text{LFAR}_{n,i}$, an array of constants read from data cards, RRT_i, ART_i, and PTOT_i, the latter three being variables specified as outputs from the demographic sector.

The plots for the life functions sector appear on pages 97-100 of this report. These plots are discussed under the section entitled "Results From the Technology and Life Function Sectors," which begins on page 96.

The Consequence Sector. In this sector the aggregate list of all consequence variables that were included in the generic model has been further consolidated. Specifically, the following consequence variables are included.

Table 7: List of Major Quantities in the Consequence Sector

Plot Symbol	Description	Equivalenced Variable Names
F	Facilities for disabled	CONSE(3), FACDIS
S	Disabled status	CONSE(4), DISS
P	Perceived environment	CONSE(5), PERENV
R	Rehabilitation rate total	CONSE(6), RRTT
U	Attitude of General Population	CONSE(7), PREAC
C	Facilities for General Population	CONSE(8), FACGEN
N	Disabled production	CONSE(9), DISP
M	Disabled employment	CONSE(10). DISE
W	Disabled workforce participation	ALF(6), WPI
I	Disabled community integration	ALF(7), DCI
D	Disabled income	PROFND(8), DISI

In the consequence sector, the attempt (See Figure 18) is to "chart" the probable consequences of life-function improvement and rehabilitation. Inputs to the sector are the aggregate life-function indicies stored in the array ALF and defined in Table 6. One would expect, for example, that disabled income, disabled production, disabled status, and disabled employment would each be functionally dependent upon (but not limited to) the life-function indices. The functional dependence is assumed to be separable and multiplicative [8,9]. It is well known, however, that such variables will also depend upon the state of the economy and government intervention [10,11]. Indeed, Worrall, et. al. [11], note that "the state of the economy will be a causal agent in determining how many people have work disability". They go on to conclude that "a strong economy with low unemployment would be an effective 'program' in the combat against work disability".

Therefore, in the model, these consequence variables are also linked with the scenario variable W(5), and V(2) employed workforce and total population respectively. The equation forms used are indicated in what follows.

$$\mathrm{DISE} = (1. - V(5)/\mathrm{POPULATION})\cdot 100\cdot f_E(H)\cdot f_E(S)\cdot f_E(M)\cdot f_E(C)\cdot f_E(O)$$

= disabled employment as a percent

$$\mathrm{DISI} = \mathrm{DISIM}\cdot f_I(\mathrm{DISE})\cdot f_I(H)\cdot f_I(S)\cdot f_I(M)\cdot f_I(C)\cdot f_I(O)$$

= disabled income in dollars

$$\mathrm{DISS} = \mathrm{DISSM}\cdot f_S(\mathrm{DISE})\cdot f_S(H)\cdot f_S(S)\cdot f_S(M)\cdot f_S(C)\cdot f_S(O)$$

= disabled status (1 = "normal" status)

$$\mathrm{DISP} = \mathrm{DISPM}\cdot f_P(\mathrm{DISE})\cdot f_P(H)\cdot f_P(S)\cdot f_P(M)\cdot f_P(C)\cdot f_P(O)$$

= disabled production (1 = "normal" production)

For simplicity in the above equations the functions f(DISE), f(H), f(S), f(M), f(C), f(O) were taken to be identical for the four above-mentioned equations. Also, in the above equations DISIM, DISSM, and DISPM are appropriate normalizing parameters which produce dimensionally consistent equations.

The causal structure for each of the four quantities disabled income, disabled status, disabled productivity, and disabled employment is practically the same for each and appears in Figure 23.

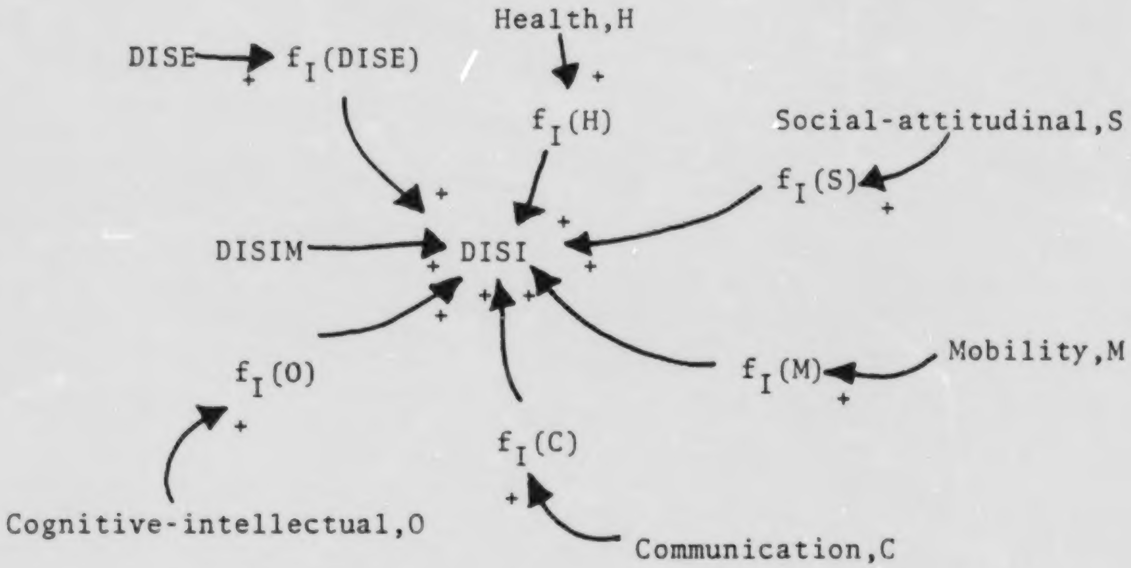

Figure 23: Typical Causal Structure for Income, Productivity, Employment, and Status of Disabled Population

In the above structure it will be observed that each of the four quantities considered are aggregated for the entire disabled population. Conceivably, it would be possible to "index" each of these four quantities by disability and to compute separate such indices for each of the fourteen case-study disabilities.

The quantities "facilities for the disabled" as well as "facilities for the general population"[1] are really quantified representations of public facilities. When public funds are spent on facilities exclusively for disabled persons, there are opportunity losses associated with not also being able to use the funds for construction of facilities for the general population.

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[1] The "general population" denotes here the total population with the possible exception of the non-ambulatory disabled.

This is particularly true with regard to transportation facilities and sheltered workshops. Any imbalance could precipitate negative reactions from either of the two parties involved, depending upon the "perceived environment". However, significant interest is mainly centered in the sentiments of the general population since they are the larger of the two lobbying groups. This is gauged by the consequence variable "attitude of general population". A negative public reaction could ultimately lead to diminished funding allocations for environmental change.

In the model, these four consequence variables "facilities for disabled", "facilities for abled", "perceived environment", and "attitude of the general population" are interrelated by means of the causal structure shown in Figure 24.

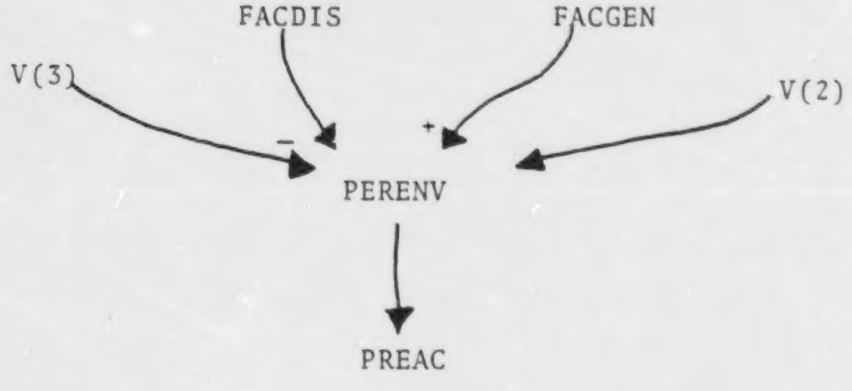

Figure 24: Interactions Among Consequence variables "facilities for the general population" (FACGEN), "facilities for disabled" (FACDIS), "perceived environment" (PEREN), and "attitude of general population" (PREAC).

Here the perceived environment, PEREN, is simply the ratio of disabled facilities per capita to abled facilities, delayed by two years. The equation form is

$$\dot{\text{PEREN}} = (\text{FACDIS}/V(2)/\text{FACGEN}/V(3) - \text{PEREN})/2., \quad \text{PEREN}\ (t_o) = .6,$$

where $\dot{\text{PEREN}}$ denotes the time rate of change of PEREN. The equation format used here is simply the first-order information delay (See 7, 12, 13). Public attitude or reaction is a proportional function of PEREN: Public attitude or PREAC is "normal" or 1 (analogous to public attitude in the base period). When PEREN departs significantly from 1 either way, there is an adverse response on the part of the public. The equation form for PREAC is

$$\text{PREAC} = f(\text{PEREN}) = \text{sgn}(\text{PEREN}) \cdot \sqrt{|1. - \text{PEREN}|}\ .$$

The equations for FACDIS, facilities for disabled, and FACGEN, facilities for general population, are simple accumulative functions of their respective funding variables, "funds for disabled facilities" expressed in dollars per annum, and "funds for general population facilities" also expressed in dollars per annum. The units on FACDIS and FACGEN represent dollars of invested capital in these respective areas.

$$\dot{\text{FACDIS}} = \text{FUNDSD} - \text{FACDOB} \cdot \text{FACDIS}$$

$$\text{FACDIS}\ (t_o) = \text{FACDIS}_o$$

$$\dot{\text{FACGEN}} = \text{FUNDSG} - \text{FACDOB} \cdot \text{FACGEN}$$

$$\text{FACGEN}\ (t_o) = \text{FACGEN}_o$$

Here FUNDSD and FUNDSG, funds for disabled facilities and funds for general facilities respectively, are program or policy inputs and as such remain constant throughout the whole simulation.

The terms FACDOB·FACDIS and FACDOB·FACGEN represent the obsolence rate of invested capital in the disabled and general facilities areas. A lifetime of thirty (30) years is assumed, giving the constant FACDOB a value of 1/30.

The three remaining quantities in the consequence sector include total rehabilitation rate, RRT, disabled workforce participation index, WPI, and disabled community integration index, DII. WPI and DII are indices having no affect upon other quantities in the set of quantities Q. WPI is, by definition, equal to the product of "average years remaining in workforce" times "average annual income" times "number of persons rehabilitated" in any given year times the "percentage of those rehabilitated who also work". Over the past few years, roughly 61% of those who are able will actually seek employment. Thus

$$WPI = AYRW \cdot AAI \cdot RRTT \cdot PRW$$

where AYRW, AAI, and PRW are treated as constants having the following values:

AYRW = 35. = average years remaining in workforce,

AAI = 12500. = average annual income in dollars per worker, and

PRW = 61.5 = percentage of those who are able that actually work.

The disabled community integration index CII is defined analogously. CII is, by definition, equal to the product of "average years remaining in life" times "number of persons rehabilitated per year". Assuming the average age of rehabilitation is roughly 30 years, the average years remaining is roughly 45.

Thus

$$CII = AYRL \cdot RRTT$$

where a value of 45 for AYRL has been assumed.

The "number of persons rehabilitated per year", RRTT is the last and perhaps most important consequence variable remaining to be described. In 1973 there were roughly 400,000 closed vocational rehabilitated cases. During the last decade, 1966 to 1975, the Federal-State Vocational Rehabilitation Program rehabilitated over 2.7 million people [11] or 270 thousand people per year on the average. Since the base period for this simulation is 1971-1975, we assumed a vocational rehabilitation rate of 300,000 persons per year as the vocational rehabilitation rate normal. Since roughly 68% of those rehabilitated would probably want employment it is reasonable to assume that 300,000/.7 or 430,000 persons were rehabilitated per year during the base period. Of the 15.5 million disabled persons aged 18 to 65 counted [11] in 1971, this is roughly 2.78% of that population. The model therefore allows for rehabilitation of 2.78% of the disabled population under normal conditions.

How this figure is changed through adjustments in rehabilitation programs is, however, not known. What is required is an operator which "maps" rehabilitation programs into rates of rehabilitation. In order to establish such an operator it would be necessary to 1) standardize the definition for rehabilitation throughout all programs, 2) collect data on the per program or program thrust costs of rehabilitation per rehabilitated person, such data being disaggregated by category of disability, and/or 3) collect data on the per program costs for each percentage point of life-function improvement, based upon quantified definitions for life-functions. One of the most significant contributions of this modeling activity is to indicate when important data items are missing in the spectrum of rehabilitation program monitoring.

The Program Sector. This is the policy sector. Here various policy combinations could be tried and the resultant effects could be observed. Included within this sector are the following variables.

Table 8: List of Major Quantities in the Program Sector

Plot Symbol	Description	Variable Name(s)
P	Funds for physical intervention	PROFND(1), FPI
E	Funds for environmental change	PROFND(2), FEC
T	Funds for training and counseling	PROFND(3), FTC
S	Funds for service delivery	PROFND(4), FSD
A	Transfer payments	PROFND(5), TP
B	Medical payments	PROFND(6), MP
C	Total of medical and transfer payments	PROFND(7), TMTP
T	Adapted environment	CONSE(1), ADAPTD
A	Total medical and transfer payments/disabled person	CONSE(2), TMTPDP

Since the model has been designed as an open-loop policy-testing model, the constants of proportionality which divide-up the available funds into the various program areas remain constant throughout the entire simulation time interval. In other words, the simulation model does not endeavor to model the decision process whose perspective is being used as a basis for model development. The purpose is not to predict how the postulated policy-maker (and his system) will behave; rather, we wish to advise and inform him about the probable dynamics of his system. Consequently, the proportionality constants specifying the funding allocations to each of the technology areas (physical intervention, environmental change, training and counseling, service delivery) are the "policy inputs" to the model.

Thus the structural format employed for each of the first four quantities listed in Table 8 above is that depicted in Figure 25 below in which each of quantities are directly proportional to total funds for rehabilitation.

Behavioral plots for this sector appear on pages 102-105 and a concomitant discussion is provided on pages 96 and 101. Plots symbols used correspond with those indicated in Table 8. Behavioral plots for the consequence sector are shown on pages 107-110 with adjoining discussion on page 106.

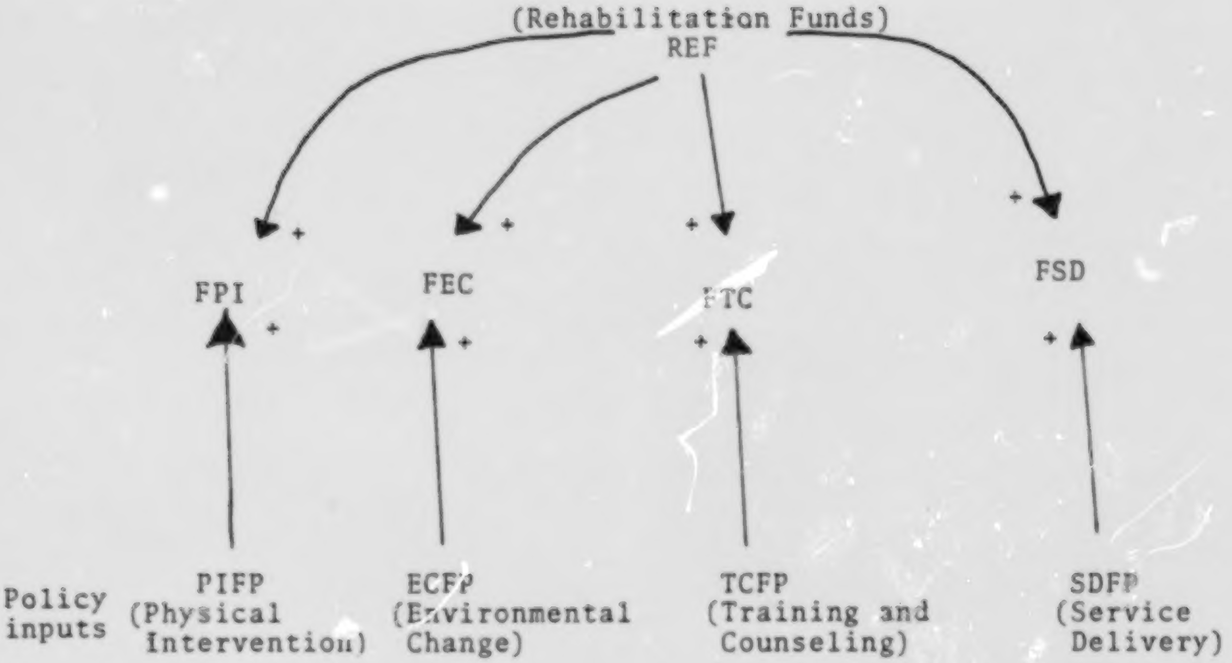
(Rehabilitation Funds)
REF
+
+
+
+
FPI
FEC
FTC
FSD
+
+
+
+
Policy inputs
PIFP (Physical Intervention)
ECFP (Environmental Change)
TCFP (Training and Counseling)
SDFP (Service Delivery)

Figure 25. A Structure for Allocation of Funds

The structure employed for the remaining five quantities is depicted in Figure 26. Consider the program thrust variable "adapted environment". Its causal structure is shown below. From its assumed structure it is easy to see how adapted environment accumulates the affects of funds allocated for environmental change. Similar growth structures are employed for transfer payments fraction (of GNP) and medical payments fraction (of GNP).

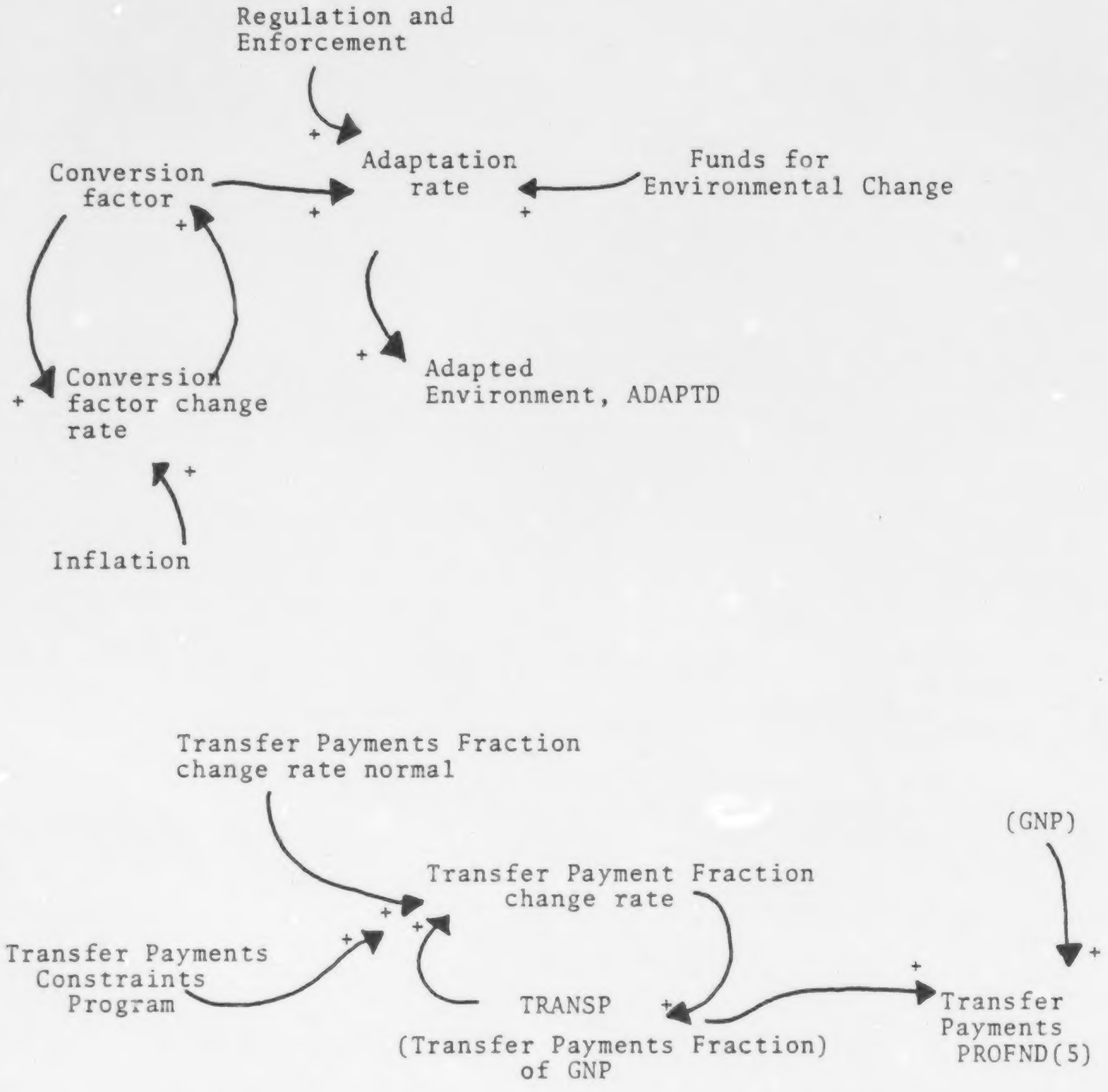
Regulation and Enforcement
+
Conversion factor
+
Adaptation rate
+
Funds for Environmental Change
+
+
Adapted Environment, ADAPTD
+
Conversion factor change rate
+
Inflation
Transfer Payments Fraction change rate normal
(GNP)
Transfer Payment Fraction change rate
+
+
+
+
Transfer Payments Constraints Program
TRANSP
+
(Transfer Payments Fraction) of GNP
+
Transfer Payments PROFND(5)

Figure 26A. (Part A) The Program Sector Structure

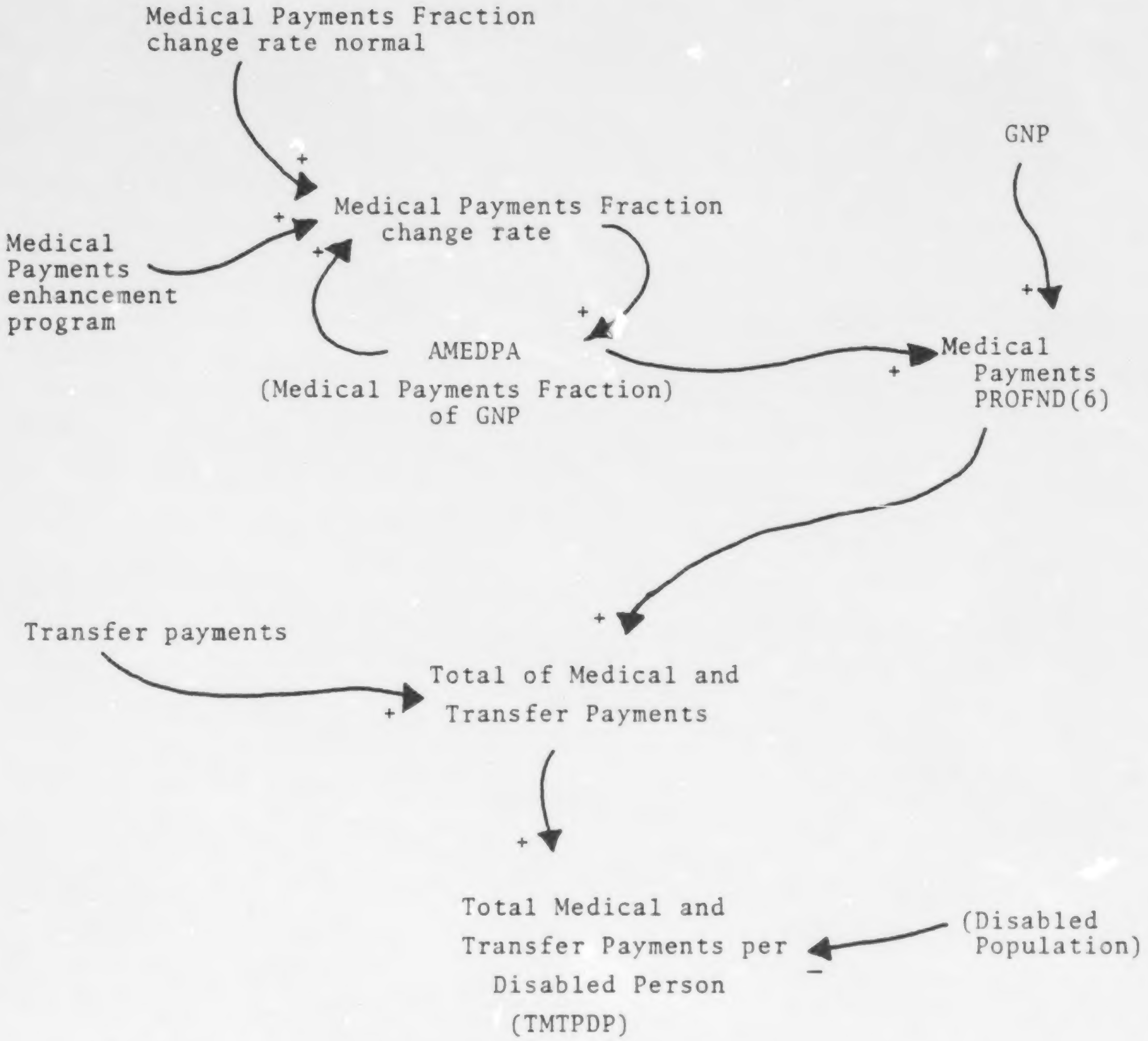
Medical Payments Fraction change rate normal
+
Medical Payments Fraction change rate
+
Medical Payments enhancement program
+
GNP
+
+
AMEDPA (Medical Payments Fraction) of GNP
+
Medical Payments PROFND(6)
+
Transfer payments
+
Total of Medical and Transfer Payments
+
Total Medical and Transfer Payments per Disabled Person (TMTPDP)
−
(Disabled Population)

Figure 26B. (Part B) The Program Sector Structure

Dynamical Behavior of the Forrester Model. Described in the remainder of this section are the dynamical behaviors indicated by each of the sectors in the model for each of the four scenarios. Most of the dynamics of interest takes place in the consequence sector. The two basic factors (inputs) to the model come (as previously indicated) from the scenario and program sectors. Observed in this section are the results for scenario-policy combinations.

Results from the Scenario Sector. Figures 27(a, b, c, and d), 28(a, b, c, and d), and 29(a, b, c, and d) depict the dynamics of the scenario sector for each of the quantities listed in Table 2, plus total and disabled population, and for each of the four scenarios described. Figures labeled a, b, and c in each of Figures 27, 28, and 29 replicate the scenario descriptions provided in Chapter 5, Volume 1, labeled the Median (M), Upper (U), Lower (L) scenarios respectively. Figures labeled d replicate the behavior of the apocalyptic scenario in which GNP, NNP, SOL, government expenditures, funds for social concerns, and rehabilitation funds actually decline from their present levels, while unemployment, tax rate, and total and disabled population continue their upward trends.

Consider first Figure 27(a, b, c, and d). The standard-of-living (S) and capability curves (C) are very similar in each of the four scenarios. Moderate increases are predicted in Figure 27a, while accelerated increases are predicted in

Figure 27b. Standard-of-living (S) and capability (C) remain at their 1978 highs for the remainder of the simulation in Figure 27c, while these variables are seen to decline in Figure 27d. Standard-of-living and capability are very similar "measures" of socioeconomic health, standard-of-living being simply GNP divided by total population while capability is NNP divided by total population. Curves for the two quantities would appear nearly superimposed were they not plotted to different scales.

In addition to capability and standard-of-living, Figure 27 also depicts the envelopes of government-expenditures and societal-willingness for each of the four scenarios. These envelopes possess lots of overlap for each of the scenarios considered due basically to the large dispersion width encompassed by each of the envelopes. Because of their width, the envelopes serve to provide very little information about the actual governmental expenditures or societal-willingness (expressed as the ratio of governmental expenditures to NNP) that would be exercised under a given scenario. One does observe the uncertainty envelope for societal-willingness becoming increasingly broad as the scenarios become more pessimistic.

In Figure 28 are depicted related "scenario" variables, including funds for social concerns (dollars), funds for rehabilitation (dollars), tax rate (fraction of NNP), productivity (NNP/employed workforce), employed workforce (people), and GNP (dollars). Causal interactions for these variables are depicted in Figure 19. One observes in Figure 28b a lower total figure for rehabilitation funds (than in Figure 28a) due to the postulated lower disabled population. Social funding is higher in Figure 28b than it is in 28a, but fails (along with rehabilitation funding) to get off the ground in Figures 28c and d. GNP actually declines in Figure 28d whereas it remains essentially constant in Figure 28c. Taxes rise sharply in Figures 28c and d while remaining at reasonably low levels in Figures 28a and b respectively.

Depicted in Figure 29 (a, b, c, and d) are the respective scenario behaviors for NNP (dollars), population, disabled population, technology ratio (dimension-less), unemployment (capita), and rehabilitation funds available per disabled person.

One observes moderate economic, population, and technological growth in Figure 29a, whereas in Figure 29b there is accelerated growth in the economy and technology while disabled population declines. Figure 29c exhibits a steady-state or static economy with continued growth in the populations depicted while technological growth is moderate. Unemployment is relatively low in Figures 29a and b, while 29c and d depict an ever increasing unemployment problem.

Rehabilitation funds per disabled person (character E) is perhaps the most interesting quantity of all in Figure 29 because it expresses how much funding is available on a per disabled person per year basis for each of the scenarios. The table which follows describes the dynamics of this variable.

Table 9: Dynamics of Rehabilitation Funds/Disabled Person

Time	Figure a (27, 28, 29) Scenario M	Figure b (27, 28, 29) Scenario U	Figure c (27, 28, 29) Scenario L	Figure d (27, 28, 29) Scenario A
1940	$102.50	$102.50	$102.50	$102.50
1950	$275.60	$275.60	$275.60	$275.60
1960	$740.90	$740.90	$740.90	$740.90
1970	$1992.00	$1992.00	$1992.00	$1992.00
1980	$5730.00	$5928.00	$2009.00	$1654.00
1990	$14630.00	$14540.00	$1019.00	$423.90
2000	$30840.00	$29230.00	$493.60	$22.28
2010	$62440.00	$106300.00	$227.10	$0.14
2020	$119500.00	$367600.00	$98.54	$0.00

Clearly rehabilitation funds per disabled person continues to expand in Figures 29a and b whereas expansion occurs only for the years 1940-1975 in Figures 29c and d, and is followed by a rampant decline in both scenarios -- down to $ 98 per-person per-year in Figure 29c and to "nothing" by the year 2000 in Figure 29d. In scenario U, there is far less total rehabilitation funding than in scenario M; even so, the rehabilitation funds per disabled person continues to grow in scenario U beyond that in scenario M. Scenario U suggests that, as those who are less severely disabled are rehabilitated out of the disabled population, there are more funds available per capita for rehabilitating those with more severe disabilities.

Scenario A (the apocalyptic scenario) suggests a rapid decline in rehabilitation funds per capita after 1980. This scenario assumes some degree of credibility for those who believe that a recurrence of a Kondratieff trough [23] is imminent. The interest in this 50-year capital-investment cycle is growing since the last recurrence of a trough in the cycle was 1932 [24].

The actual funds for rehabilitation, which is not clearly delineated in the figures, postulated by the four scenarios is given in Table 10 below.

Table 10: Total Rehabilitation Funding (in Dollars) by Scenario

Time	Scenario M	Scenario U	Scenario L	Scenario A
1940	$1.977x10^{9}$	$1.977x10^{9}$	$1.977x10^{9}$	$1.977x10^{9}$
1950	$6.143x10^{9}$	$6.143x10^{9}$	$6.143x10^{9}$	$6.143x10^{9}$
1960	$1.909x10^{10}$	$1.909x10^{10}$	$1.909x10^{10}$	$1.909x10^{10}$
1970	$5.932x10^{10}$	$5.932x10^{10}$	$5.932x10^{10}$	$5.932x10^{10}$
1980	$1.884x10^{11}$	$1.948x10^{11}$	$6.780x10^{10}$	$5.436x10^{10}$
1990	$5.152x10^{11}$	$4.994x10^{11}$	$3.848x10^{10}$	$1.492x10^{10}$
2000	$1.162x10^{12}$	$1.024x10^{12}$	$2.086x10^{10}$	$8.398x10^{8}$
2010	$2.354x10^{12}$	$1.838x10^{12}$	$1.073x10^{10}$	$5.446x10^{7}$
2020	$4.503x10^{12}$	$3.138x10^{12}$	$5.213x10^{9}$	$7.548x10^{3}$

Rehabilitation funding declines more rapidly in scenario A than in scenario L due to an actual decline in NNP. The prospect of an actual decline in NNP was considered highly improbable by scenario designers in the parent study because of the government's propensity for deficit financing, not to mention its ability to make money, to lower interest rates, etc. Since the apocalyptic scenario is theoretically possible but highly improbable, its use was not considered in the parent study.

```
                                                SCALES OF PLOT
0.220E 04                0.117E 05                0.211E 05                0.306E 05                0.400E 05   CAPABILITY       C
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEND       W
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEN2       I
0.500E-01                0.104E 01                0.202E 01                0.301E 01                0.400E 01   WILLINGNS1       1
0.500E-01                0.104E 01                0.202E 01                0.301E 01                0.400E 01   WILLINGNS2       2
0.240E 04                0.143E 05                0.262E 05                0.381E 05                0.500E 05   STNDOFLIVG       S

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 W       1                |                        |                        |                        | WI 12
1942 C       1                |                        |                        |                        | CW CI 12 CS
1944 C       1                |                        |                        |                        | CW CI 12 CS
1946 WC      1                |                        |                        |                        | WI 12 CS
1948 |C      1                |                        |                        |                        | CW CI 12 CS
1950 |C      1                |                        |                        |                        | CW CI 12 CS
1952 |WC     1                |                        |                        |                        | WI 12 WS
1954 |WC     1                |                        |                        |                        | WI 12 CS
1956 |WC     1                |                        |                        |                        | WI 12 CS
1958 |WC     1                |                        |                        |                        | WI 12 CS
1960 | WC    1                |                        |                        |                        | WI 12 WS
1962 | WC    1                |                        |                        |                        | WI 12 CS
1964 | WSC   1                |                        |                        |                        | WI 12
1966 |  WC   1                |                        |                        |                        | WI 12 CS
1968 |  WC   1                |                        |                        |                        | WI 12 CS
1970 |  WSC  1                |                        |                        |                        | WI 12
1972 |  IWC  1                |                        |                        |                        | 12 CS
1974 |  IWSC2 1               |                        |                        |                        |
1976 |   IWC2 1               |                        |                        |                        | CS
1978 |   I WC  1              |                        |                        |                        | W2 WS
1980 |   I 2WC 1              |                        |                        |                        | WS
1982 |   I 2 WC 1             |                        |                        |                        | WS
1984 |   I 2 SC 1             |                        |                        |                        | CW
1986 |   12   SC 1            |                        |                        |                        | CW
1988 |   12    SC1            |                        |                        |                        | CW
1990 |    I     SCW           |                        |                        |                        | WI 12
1992 |   2I      SC W         |                        |                        |                        | CI
1994 |   2I      S C W        |                        |                        |                        | CI
1996 |   2I       S C   W     |                        |                        |                        | CI
1998 |   2I        SIC    W   |                        |                        |                        |
2000 |   2I          1 C     W|                        |                        |                        | IS
2002 |  2  I          1 C     |W                       |                        |                        | IS
2004 |  2  I           1 C    |    W                   |                        |                        | IS
2006 |  2  I            1  C  |       W                |                        |                        | IS
2008 |  2  I            1 S C |            W           |                        |                        |
2010 |  2  I             1 S  C                W       |                        |                        |
2012 |  2   I             1  S| C                   W  |                        |                        |
2014 | 2    I              1  S   C                    |  W                     |                        |
2016 | 2    I               1 | S   C                  |         W              |                        |
2018 | 2    I                1|   S   C                |                W       |                        |
2020 | 2    I                 |1    S   C              |                        W                        |
2022 | 2     I                | 1     S   C            |                        |        W               |
2024 | 2     I                |  1      S   C          |                        |                  W     |
2026 | 2     I                |   1       S    C       |                        |                        |

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 27a: Medial Scenario--Capability(C), Gov. Expenditures 1 (W), Gov. Expenditures 2(I), Willingness 1(1), Willingness 2(2), Standard of Living(S)

```
                                                SCALES OF PLOT
0.220E 04                0.117E 05                0.211E 05                0.306E 05                0.400E 05   CAPABILITY       C
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEND       W
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEN2       I
0.500E-01                0.104E 01                0.202E 01                0.301E 01                0.400E 01   WILLINGNS1       1
0.500E-01                0.104E 01                0.202E 01                0.301E 01                0.400E 01   WILLINGNS2       2
0.240E 04                0.143E 05                0.262E 05                0.381E 05                0.500E 05   STNDOFLIVG       S

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 W       1                I                        I                        I                        I WI 12
1942 C       1                I                        I                        I                        I CW CI 12 CS
1944 C       1                I                        I                        I                        I CW CI 12 CS
1946 WC      1                I                        I                        I                        I WI 12 CS
1948 IC      1                I                        I                        I                        I CW CI 12 CS
1950 IC      1                I                        I                        I                        I CW CI 12 CS
1952 IWC     1                I                        I                        I                        I WI 12 WS
1954 IWC     1                I                        I                        I                        I WI 12 CS
1956 IWC     1                I                        I                        I                        I WI 12 CS
1958 IWC     1                I                        I                        I                        I WI 12 CS
1960 I WC    1                I                        I                        I                        I WI 12 WS
1962 I WC    1                I                        I                        I                        I WI 12 CS
1964 I WSC   1                I                        I                        I                        I WI 12
1966 I  WC   1                I                        I                        I                        I WI 12 CS
1968 I  WC   1                I                        I                        I                        I WI 12 CS
1970 I  WSC  1                I                        I                        I                        I WI 12
1972 I  IWC  1                I                        I                        I                        I 12 CS
1974 I  IWSC2 1               I                        I                        I                        I
1976 I   IWSC 1               I                        I                        I                        I C2
1978 I   I WSC1               I                        I                        I                        I W2
1980 I   I 2WSC               I                        I                        I                        I C1
1982 I   I2  WSC              I                        I                        I                        I C1
1984 I   I2   W1C             I                        I                        I                        I 1S
1986 I   I     WS C           I                        I                        I                        I WI 12
1988 I   I     1WS C          I                        I                        I                        I I2
1990 I   2I     1 WS C        I                        I                        I                        I
1992 I  2 I     1   WS C      I                        I                        I                        I
1994 I  2 I     1    W S C    I                        I                        I                        I
1996 I  2 I     1       WS C  I                        I                        I                        I
1998 I  2 I      1        WS  C                        I                        I                        I
2000 I 2  I      1           WI  C                     I                        I                        I WS
2002 I 2   I     1            IWS  C                   I                        I                        I
2004 I 2   I      1           I    W   C               I                        I                        I WS
2006 I 2   I      1           I       W   C            I                        I                        I WS
2008 I 2   I      1           I          S W  C        I                        I                        I
2010 I2    I      1           I              S W  C    I                        I                        I
2012 I2     I      1          I                  S  W  C                        I                        I
2014 I2     I      1          I                      S I  W C                   I                        I
2016 I2     I      1          I                        I  S      C              I                        I CW
2018 I2     I       1         I                        I       S       CW       I                        I
2020 I2     I       1         I                        I             S        C W                        I
2022 I2      I       1        I                        I                   S    I    C   W               I
2024 2       I       1        I                        I                        I  S          C    W     I
2026 2       I       1        I                        I                        I          S           C I

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 27b: Upper Scenario--Capability(C), Gov. Expenditures 1 (W), Gov. Expenditures 2(I), Willingness 1(1), Willingness 2(2), Standard of Living(S)

```
                                               SCALES OF PLOT
0.220E 04                0.117E 05                0.211E 05                0.306E 05                0.400E 05   CAPABILITY       C
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEND       W
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEN2       I
0.500E-01                0.104E 01                0.202E 01                0.301E 01                0.400E 01   WILLINGNS1       1
0.500E-01                0.104E 01                0.202E 01                0.301E 01                0.400E 01   WILLINGNS2       2
0.240E 04                0.143E 05                0.262E 05                0.381E 05                0.500E 05   STNDOFLIVG       S

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 W       1                I                        I                        I                        I WI 12
1942 C       1                I                        I                        I                        I CW CI 12 CS
1944 C       1                I                        I                        I                        I CW CI 12 CS
1946 WC      1                I                        I                        I                        I WI 12 CS
1948 IC      1                I                        I                        I                        I CW CI 12 CS
1950 IC      1                I                        I                        I                        I CW CI 12 CS
1952 IWC     1                I                        I                        I                        I WI 12 WS
1954 IWC     1                I                        I                        I                        I WI 12 CS
1956 IWC     1                I                        I                        I                        I WI 12 CS
1958 IWC     1                I                        I                        I                        I WI 12 CS
1960 I WC    1                I                        I                        I                        I WI 12 WS
1962 I WC    1                I                        I                        I                        I WI 12 CS
1964 I WSC   1                I                        I                        I                        I WI 12
1966 I  WC   1                I                        I                        I                        I WI 12 CS
1968 I  WC   1                I                        I                        I                        I WI 12 CS
1970 I  WSC  1                I                        I                        I                        I WI 12
1972 I  IWC  1                I                        I                        I                        I 12 CS
1974 I  IWSC2 1               I                        I                        I                        I
1976 I   IWC2  1              I                        I                        I                        I WS
1978 I   ISC2   1             I                        I                        I                        I CW
1980 I   ISCW    1            I                        I                        I                        I W2
1982 I   ISC2W    1           I                        I                        I                        I
1984 I   ISC2 W    1          I                        I                        I                        I
1986 I   ISC2  W    1         I                        I                        I                        I
1988 I   ISC2   W     1       I                        I                        I                        I
1990 I    IC2     W    1      I                        I                        I                        I IS
1992 I    IC2       W    1    I                        I                        I                        I IS
1994 I    IC2        W     1  I                        I                        I                        I CS
1996 I    IC2           W    1I                        I                        I                        I CS
1998 I    IC2             W   I1                       I                        I                        I CS
2000 I    IC2                WI   1                    I                        I                        I CS
2002 I     C2                 IW    1                  I                        I                        I CI CS
2004 I     C2                 I    W   1               I                        I                        I CI CS
2006 I     IC                 I       W   1            I                        I                        I C2 IS
2008 I     IC                 I            W  1        I                        I                        I C2 IS
2010 I     IC                 I                W  1    I                        I                        I C2 IS
2012 I     SC                 I                     W 1I                        I                        I CI C2
2014 I     SC                 I                        I  W                     I                        I CI WI C2
2016 I     SC                 I                        I       1 W              I                        I CI C2
2018 I     SC                 I                        I            1   W       I                        I CI C2
2020 I     SC                 I                        I                  1     W                        I CI C2
2022 I     SCI                I                        I                        1        W               I C2
2024 I     SCI                I                        I                        I      1           W     I C2
2026 I     SCI                I                        I                        I             1          I C2

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 27c: Lower Scenario--Capability(C), Gov. Expenditures 1(W), Gov. Expenditures 2(I), Willingness 1(1), Willingness 2(2), Standard of Living(S)

```
                                                SCALES OF PLOT
0.220E 04                0.117E 05                0.211E 05                0.306E 05                0.400E 05   CAPABILITY       C
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEND       W
0.100E 12                0.167E 13                0.325E 13                0.482E 13                0.640E 13   GOV EXPEN2       I
0.500E-01                0.104E 01                0.202F 01                0.301F 01                0.400E 01   WILLINGNS1       1
0.500E-01                0.104E 01                0.202E 01                0.301E 01                0.400E 01   WILLINGNS2       2
0.240E 04                0.143E 05                0.262E 05                0.381E 05                0.500E 05   STNDOFLIVG       S

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 W       1                |                        |                        |                        | WI 12
1942 C       1                |                        |                        |                        | CW CI 12 CS
1944 C       1                |                        |                        |                        | CW CI 12 CS
1946 WC      1                |                        |                        |                        | WI 12 CS
1948 |C      1                |                        |                        |                        | CW CI 12 CS
1950 |C      1                |                        |                        |                        | CW CI 12 CS
1952 |WC     1                |                        |                        |                        | WI 12 WS
1954 |WC     1                |                        |                        |                        | WI 12 CS
1956 |WC     1                |                        |                        |                        | WI 12 CS
1958 |WC     1                |                        |                        |                        | WI 12 CS
1960 | WC    1                |                        |                        |                        | WI 12 WS
1962 | WC    1                |                        |                        |                        | WI 12 CS
1964 | WSC   1                |                        |                        |                        | WI 12
1966 |  WC   1                |                        |                        |                        | WI 12 CS
1968 |  WC   1                |                        |                        |                        | WI 12 CS
1970 |  WSC  1                |                        |                        |                        | WI 12
1972 |  IWC  1                |                        |                        |                        | 12 CS
1974 |  IWSC2 1               |                        |                        |                        |
1976 |   IC 2  1              |                        |                        |                        | CW CS
1978 |   ICW 2  1             |                        |                        |                        | CS
1980 |   IC W2    1           |                        |                        |                        | IS
1982 |   IC  W      1         |                        |                        |                        | W2 IS
1984 |   C    W       1       |                        |                        |                        | CI W2 CS
1986 |   C    2W        1     |                        |                        |                        | CI CS
1988 |   C     2W          1  |                        |                        |                        | CI CS
1990 |  SCI    2  W           |                        |                        |                        |
1992 |  SCI    2    W         |  1                     |                        |                        |
1994 |  C I     2    W        |      1                 |                        |                        | CS
1996 |  C I     2       W     |           1            |                        |                        | CS
1998 |  C I      2        W   |                1       |                        |                        | CS
2000 | SC I      2           W|                     1  |                        |                        |
2002 | C   I      2           |W                       |  1                     |                        | CS
2004 | C   I      2           |    W                   |         1              |                        | CS
2006 | C   I       2          |       W                |                 1      |                        | CS
2008 | C   I       2          |            W           |                        | 1                      | CS
2010 | C   I        2         |                W       |                        |           1            | CS
2012 |SC    I       2         |                     W  |                        |                       1|
2014 |C     I        2        |                        |  W                     |                        | CS
2016 |C     I         2       |                        |         W              |                        | CS
2018 |C     I         2       |                        |                W       |                        | CS
2020 |C     I          2      |                        |                        W                        | CS
2022 |C      I          2     |                        |                        |        W               | CS
2024 |C      I          2     |                        |                        |                  W     | CS
2026 C       I           2    |                        |                        |                        | CS

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 22d: Apocalyptic Scenario--Capability(C), Gov. Expenditures 1(W), Gov. Expenditures 2(I), Willingness 1(1), Willingness 2(2), Standard of Living(S)

```
                                                SCALES OF PLOT
0.140E 11                0.376E 13                0.751E 13                0.113E 14                0.150E 14   SOC. FUNDS       S
0.200E 10                0.375E 13                0.750E 13                0.113E 14                0.150E 14   REHAB FUND       R
0.190E 00                0.589E 01                0.116E 02                0.173E 02                0.230E 02   TAX RATE         .
0.600E 04                0.145E 05                0.230E 05                0.315E 05                0.400E 05   PRODUCTITY       P
0.480E 08                0.922E 08                0.137E 09                0.181E 09                0.225E 09   EMPLOYD WF       I
0.310E 12                0.278E 13                0.525E 13                0.773E 13                0.102E 14   GNP              G

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 I                        |                        |                        |                        |
1942 SI                       |                        |                        |                        |  SR S. SP SG
1944 SPI                      |                        |                        |                        |  SR S. SG
1946 SGPI                     |                        |                        |                        |  SR S.
1948 SGP I                    |                        |                        |                        |  SR S.
1950 SG P I                   |                        |                        |                        |  SR S.
1952 S G P I                  |                        |                        |                        |  SR S.
1954 S G  P  I                |                        |                        |                        |  SR S.
1956 S G  P   I               |                        |                        |                        |  SR S.
1958 S  G  P   I              |                        |                        |                        |  SR S.
1960 S  G   P    I            |                        |                        |                        |  SR S.
1962 S   G   P    I           |                        |                        |                        |  SR S.
1964 S   G    P    I          |                        |                        |                        |  SR S.
1966 RS   G    P     I        |                        |                        |                        |  S.
1968 RS   G     P     I       |                        |                        |                        |  S.
1970 RS    G     P      I     |                        |                        |                        |  S.
1972 RS     G     P       I   |                        |                        |                        |  S.
1974 |S     G      P       I  |                        |                        |                        |  SR S.
1976 |S      G      P        I|                        |                        |                        |  SR S.
1978 |RS      G      P        |I                       |                        |                        |  R.
1980 |RS       G      P       |  I                     |                        |                        |  R.
1982 |.S        G       P     |    I                   |                        |                        |  SR
1984 |.RS        G       P    |      I                 |                        |                        |
1986 |.RS         G       P   |        I               |                        |                        |
1988 |. RS         G       P  |          I             |                        |                        |
1990 |. RS          G        P|             I          |                        |                        |
1992 | . RS          G        P               I        |                        |                        |
1994 | .  RS           G      |P                I      |                        |                        |
1996 | .   RS           G     |  P                 I   |                        |                        |
1998 | .    RS            G   |   P                   I|                        |                        |
2000 | .     R S            G |     P                  |I                       |                        |
2002 | .      R S            G|       P                |   I                    |                        |
2004 | .       R  S           |G       P               |      I                 |                        |
2006 | .         R  S         |  G       P             |         I              |                        |
2008 | .           R   S      |     G      P           |            I           |                        |
2010 |  .            R    S   |       G      P         |                I       |                        |
2012 |  .              R      S         G      P       |                   I    |                        |
2014 |  .                R    |   S        G     P     |                      I |                        |
2016 |  .                   R |        S      G    P   |                        | I                      |
2018 |  .                     |R             S   G   P |                        |     I                  |
2020 |  .                     |    R               S G P                        |         I              |
2022 |   .                    |        R               |GP S                    |             I          |
2024 |   .                    |              R         |    P        S          |                 I      |  PG
2026 |   .                    |                     R  |       P G             S|                     I  |

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100        DUPLICATES
```

Figure 28a: Medial Scenario--Societal Funds(S), Rehab Funds(R), Tax rate(.), Productivity(P), Employed Workforce(I), GNP(G)

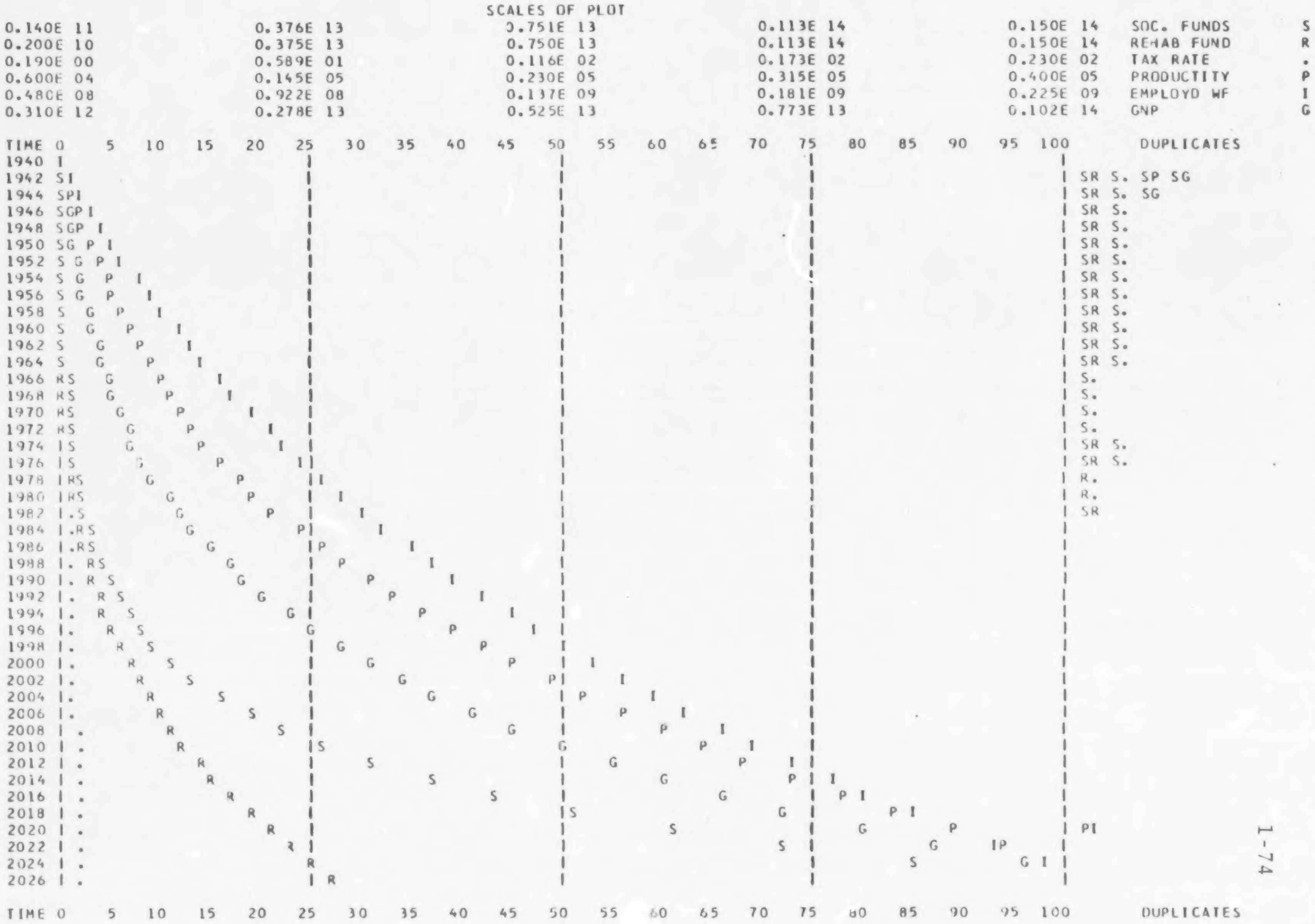

Figure 28b: Upper Scenario--Societal Funds(S), Rehab Funds(R), Tax Rate(.), Productivity(P), Employed Workforce(I), GNP(G)

```
                                                SCALES OF PLOT
0.140E 11                0.376E 13                0.751E 13                0.113E 14                0.150E 14   SOC. FUNDS       S
0.200E 10                0.375E 13                0.750E 13                0.113E 14                0.150E 14   REHAB FUND       R
0.190E 00                0.589E 01                0.116E 02                0.173E 02                0.230E 02   TAX RATE         .
0.600E 04                0.145E 05                0.230E 05                0.315E 05                0.400E 05   PRODUCTITY       P
0.480E 08                0.922E 08                0.137E 09                0.181E 09                0.225E 09   EMPLOYD WF       I
0.310E 12                0.278E 13                0.525E 13                0.773E 13                0.102E 14   GNP              G

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 I                        |                        |                        |                        |
1942 SI                       |                        |                        |                        | SR S. SP SG
1944 SPI                      |                        |                        |                        | SR S. SG
1946 SGPI                     |                        |                        |                        | SR S.
1948 SGP I                    |                        |                        |                        | SR S.
1950 SG P I                   |                        |                        |                        | SR S.
1952 S G P I                  |                        |                        |                        | SR S.
1954 S G  P  I                |                        |                        |                        | SR S.
1956 S G  P   I     .         |                        |                        |                        | SR S.
1958 S  G  P   I              |                        |                        |                        | SR S.
1960 S  G   P    I            |                        |                        |                        | SR S.
1962 S   G   P    I           |                        |                        |                        | SR S.
1964 S   G    P    I          |                        |                        |                        | SR S.
1966 RS   G    P     I        |                        |                        |                        | S.
1968 RS   G     P     I       |                        |                        |                        | S.
1970 RS    G     P      I     |                        |                        |                        | S.
1972 RS     G     P       I   |                        |                        |                        | S.
1974 IS     G      P       I  |                        |                        |                        | SR S.
1976 IS      G     P         I|                        |                        |                        | SR S.
1978 RS      G     P          |                        |                        |                        | S.
1980 RS.     G     P          | I                      |                        |                        |
1982 RS.      G    P          |   I                    |                        |                        |
1984 RS .     G    P          |    I                   |                        |                        |
1986 RS .     G   P           |      I                 |                        |                        |
1988 RS  .     G  P           |        I               |                        |                        |
1990 S    .    G  P           |          I             |                        |                        | SR
1992 S     .   G  P           |            I           |                        |                        | SR
1994 S      .   G P           |              I         |                        |                        | SR
1996 S        . G P           |                I       |                        |                        | SR
1998 S         .G P           |                  I     |                        |                        | SR
2000 S           .P           |                    I   |                        |                        | SR .G
2002 S           GP .         |                      I |                        |                        | SR
2004 S           PG   .       |                        |I                       |                        | SR
2006 S           PG      .    |                        |  I                     |                        | SR
2008 S           PG          .|                        |    I                   |                        | SR
2010 S           P G          |   .                    |       I                |                        | SR
2012 S           P G          |        .               |         I              |                        | SR
2014 S           P  G         |              .         |            I           |                        | SR
2016 S           P  G         |                     .  |               I        |                        | SR
2018 S           P   G        |                        |    .             I     |                        | SR
2020 S           P   G        |                        |              .      I  |                        | SR
2022 S           P    G       |                        |                        I.                       | SR
2024 S          P     G       |                        |                        |  I           .         | SR
2026 I          P      G      |                        |                        |     I                  | SR

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 28c: Lower Scenario--Societal Funds(S), Rehab Funds(R), Tax Rate(.), Productivity(P), Employed Workforce (I), GNP(G)

```
                                                SCALES OF PLOT
0.140E 11                0.376E 13                0.751E 13                0.113E 14                0.150E 14   SOC. FUNDS       S
0.200E 10                0.375E 13                0.750E 13                0.113E 14                0.150E 14   REHAB FUND       R
0.190E 00                0.589E 01                0.116E 02                0.173E 02                0.230E 02   TAX RATE         .
0.600E 04                0.145E 05                0.230E 05                0.315E 05                0.400E 05   PRODUCTITY       P
0.480E 08                0.922E 08                0.137E 09                0.181E 09                0.225E 09   EMPLOYD WF       I
0.310E 12                0.278E 13                0.525E 13                0.773E 13                0.102E 14   GNP              G

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 I                        |                        |                        |                        | SI
1942 SI                       |                        |                        |                        | SR S. SP SG
1944 SPI                      |                        |                        |                        | SR S. SG
1946 SGPI                     |                        |                        |                        | SR S.
1948 SGP I                    |                        |                        |                        | SR S.
1950 SG P I                   |                        |                        |                        | SR S.
1952 S G P I                  |                        |                        |                        | SR S.
1954 S G  P  I                |                        |                        |                        | SR S.
1956 S G  P   I               |                        |                        |                        | SR S.
1958 S  G  P   I              |                        |                        |                        | SR S.
1960 S  G   P    I            |                        |                        |                        | SR S.
1962 S   G   P    I           |                        |                        |                        | SR S.
1964 S   G    P    I          |                        |                        |                        | SR S.
1966 RS   G    P     I        |                        |                        |                        | S.
1968 RS   G     P     I       |                        |                        |                        | S.
1970 RS    G     P      I     |                        |                        |                        | S.
1972 RS     G     P       I   |                        |                        |                        | S.
1974 |S     G      P       I  |                        |                        |                        | SR S.
1976 |S     G     P         I |                        |                        |                        | SR S.
1978 R S    G    P           I|                        |                        |                        | S.
1980 R S    G   P             |                        |                        |                        | S.
1982 R S.   G  P              | I                      |                        |                        |
1984 R  S.  G  P              |  I                     |                        |                        |
1986 R   S. G P               |   I                    |                        |                        |
1988 R   S .GP                |    I                   |                        |                        |
1990 R    S .                 |     I                  |                        |                        | .P .G
1992 R     SP .               |      I                 |                        |                        | PG
1994 R     PS    .            |       I                |                        |                        | PG
1996 R    PG  S    .          |         I              |                        |                        |
1998 |   P G    S      .      |          I             |                        |                        |
2000 |   P G      S        .  |           I            |                        |                        |
2002 |  P  G        S         | .          I           |                        |                        |
2004 |  P  G           S      |       .      I         |                        |                        |
2006 | P   G               S  |               .        |                        |                        | .I
2008 |P    G                  |S               I       |.                       |                        |
2010 |P    G                  |     S            I     |           .            |                        |
2012 |     G                  |           S       I    |                        |.                       | RP
2014 |     G                  |                   S I  |                        |                  .     |
2016 |    G                   |                      I |  S                     |                        |
2018 |    G                   |                        |             S          |                        |
2020 |    G                   |                        |I                       |S                       |
2022 |    G                   |                        |  I                     |               S        |
2024 |    G                   |                        |    I                   |                        |
2026 |    G                   |                        |     I                  |                        |

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 28d: Apocalyptic Scenario--Societal Funds(S), Rehab Funds (R), Tax Rate(.), Productivity(P), Employed Workforce(I), GNP(G)

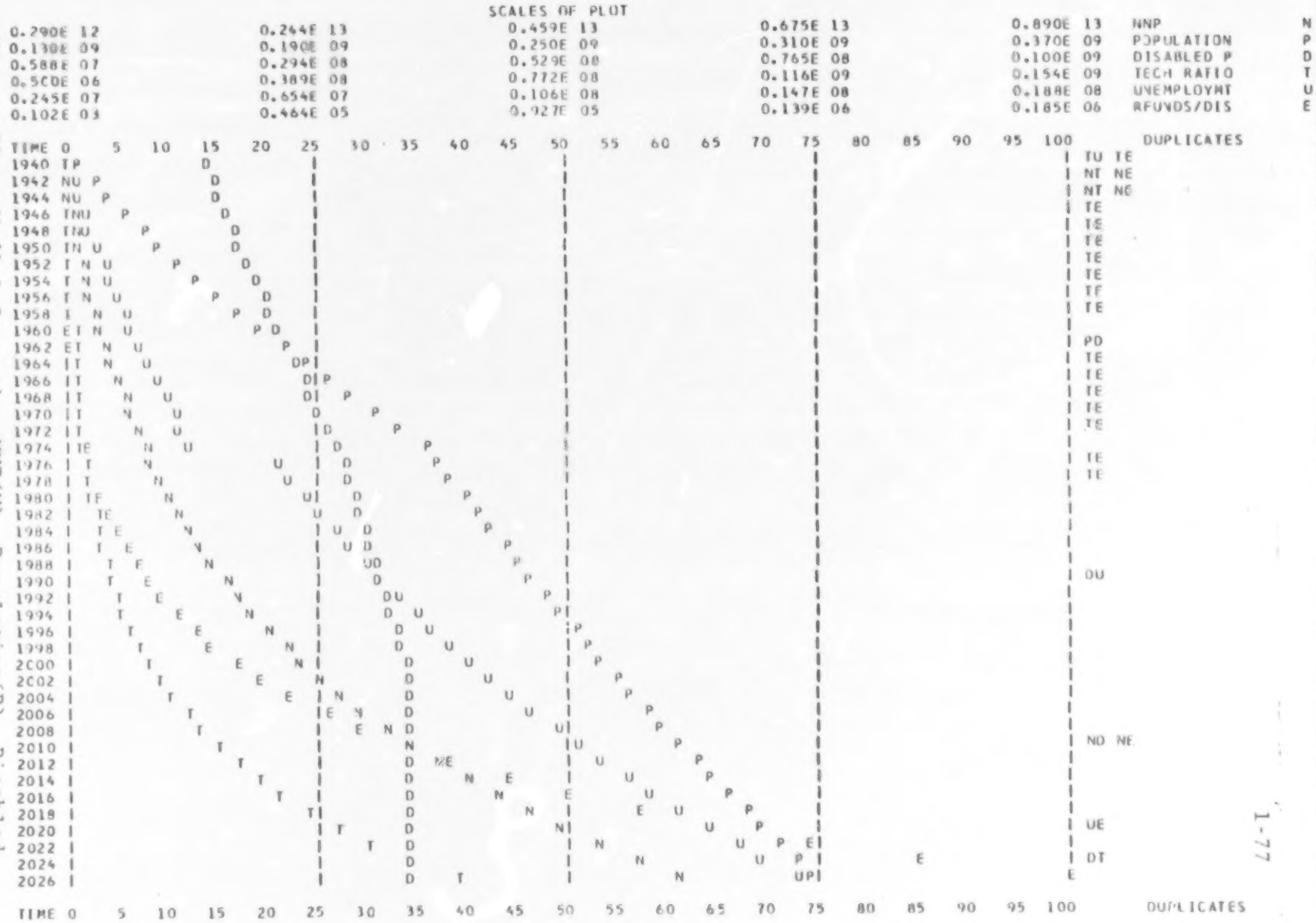

Figure 29a: Medial Scenario--NNP(N), Population(P), Disabled Population(D), Technology Ratio(T), Unemployment(U), Rehab Funds/ Disabled Person(E)

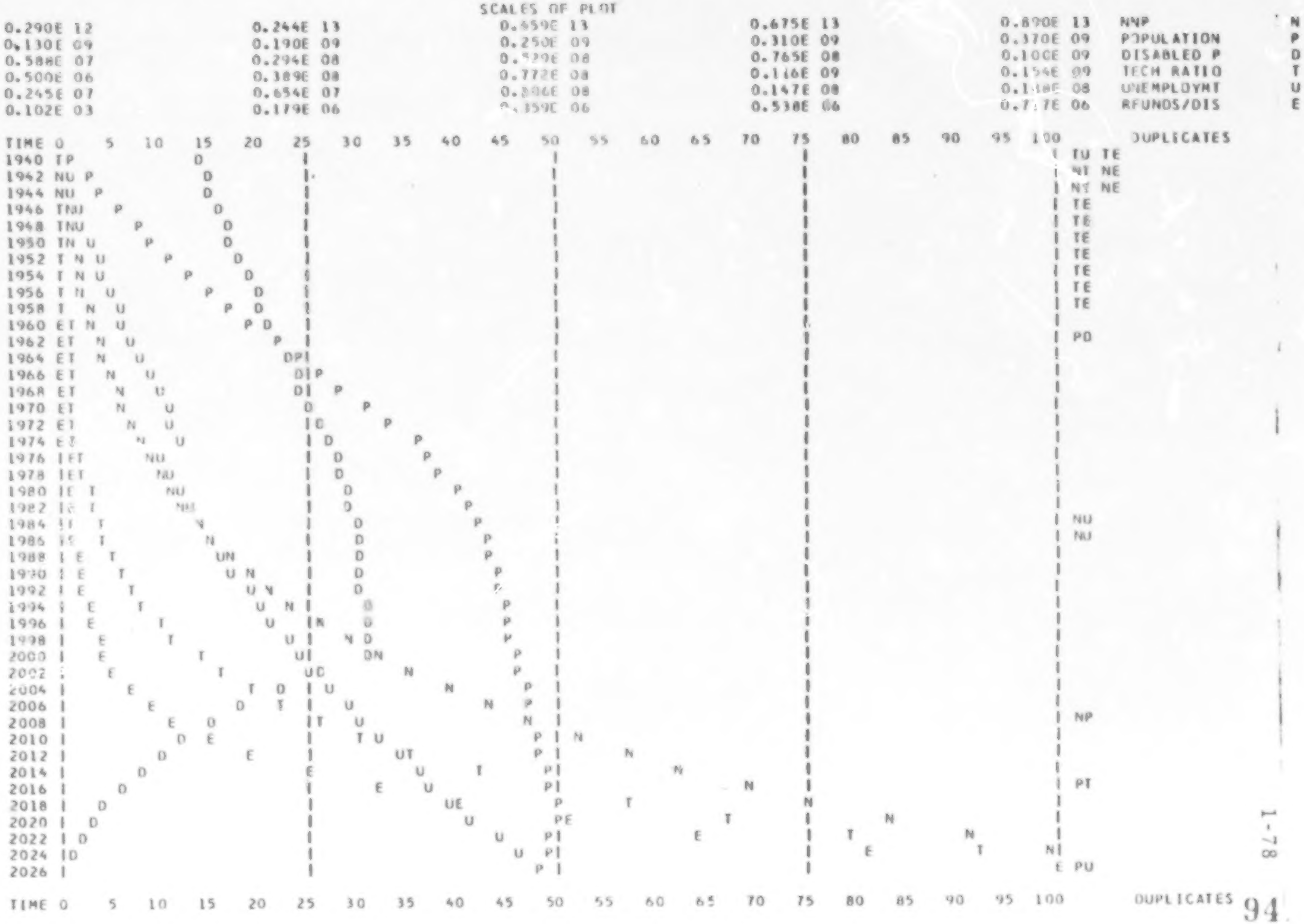

Figure 29b: Upper Scenario--NNP(N), Population(P), Disabled Population(D), Technology Ratio(T), Unemployment(U), Rehab Funds/Disabled Person(E)

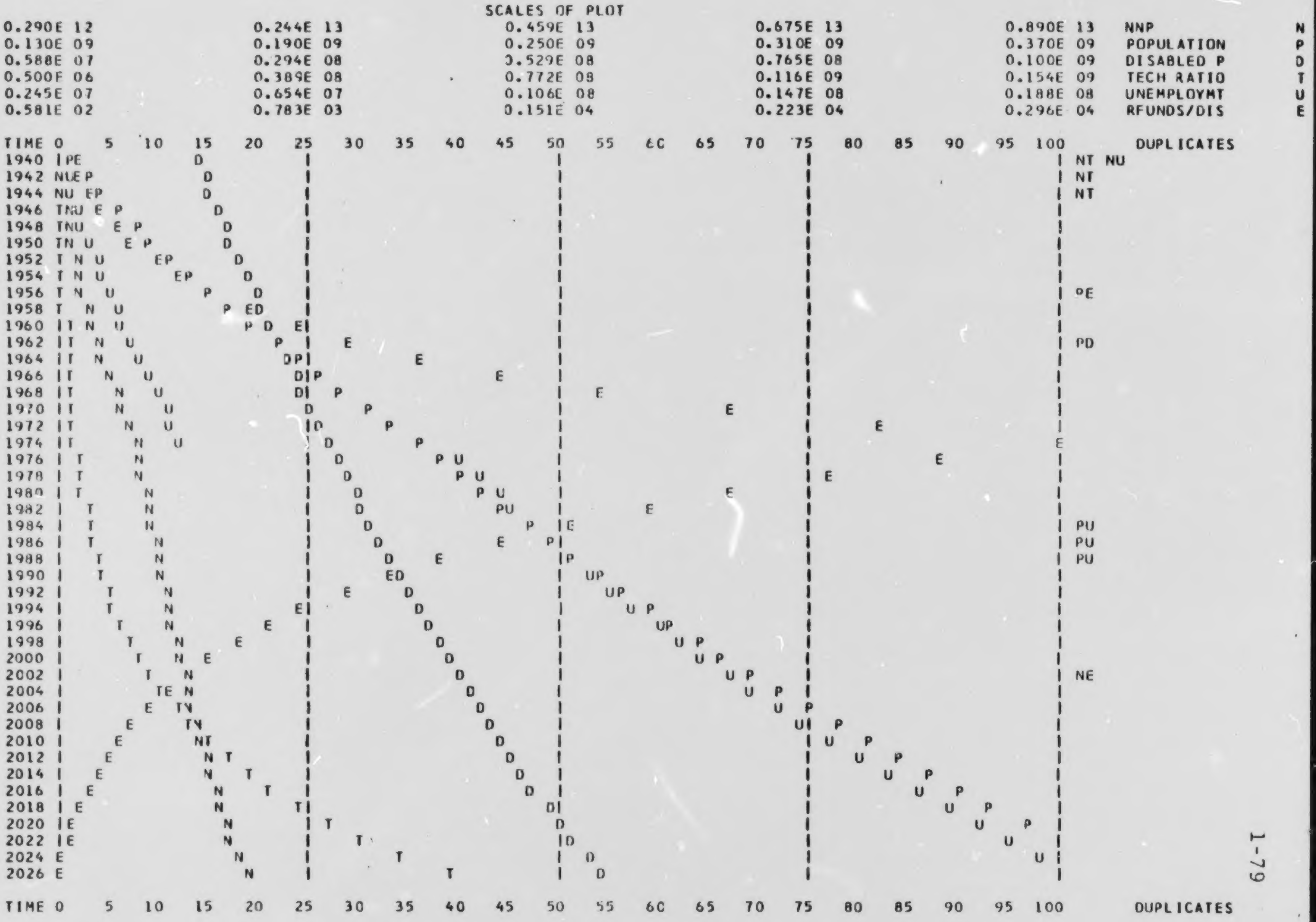

Figure 29c: Lower Scenario--NNP(N), Population(P), Disabled Population(D), Technology Ratio(T), Unemployment(U), Rehab Funds/ Disabled Person(E)

```
                                                SCALES OF PLOT
0.290E 12                0.244E 13                0.459E 13                0.675E 13                0.890E 13   NNP              N
0.130E 09                0.190E 09                0.250E 09                0.310E 09                0.370E 09   POPULATION       P
0.588E 07                0.294E 08                0.529E 08                0.765E 08                0.100E 09   DISABLED P       D
0.500E 06                0.389E 08                0.772E 08                0.116E 09                0.154E 09   TECH RATIO       T
0.245E 07                0.654E 07                0.106E 08                0.147E 08                0.188E 08   UNEMPLOYMT       U
0.167E-05                0.740E 03                0.148E 04                0.222E 04                0.296E 04   RFUNDS/DIS       E

TIME 0    5    10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95   100       DUPLICATES
1940 TP E          D          |                        |                        |                        | TU
1942 NU PE          D         |                        |                        |                        | NT
1944 NU  PE         D         |                        |                        |                        | NT
1946 TNU   P         D        |                        |                        |                        | PE
1948 TNU     P        D       |                        |                        |                        | PE
1950 TN U     P       D       |                        |                        |                        | PE
1952 T N U      P      D      |                        |                        |                        | PE
1954 T N U        PE    D     |                        |                        |                        |
1956 T N  U         P E  D    |                        |                        |                        |
1958 T  N  U          P  DE   |                        |                        |                        |
1960 |T N  U            P D   E                        |                        |                        |
1962 |T  N  U              P  |     E                  |                        |                        | PD
1964 |T  N   U              DP|           E            |                        |                        |
1966 |T   N   U              D|P                  E    |                        |                        |
1968 |T    N   U             D|  P                     |    E                   |                        |
1970 |T    N    U             D     P                  |                E       |                        |
1972 |T     N   U             |D      P                |                        |      E                 |
1974 |T      N   U            | D        P             |                        |                        E
1976 | T     N                |  D        P  U         |                        |       E                |
1978 | T    N                 |  D         P  U        |                  E     |                        |
1980 | T    N                 |   D          P U       |     E                  |                        |
1982 | T    N                 |   D           P U E    |                        |                        |
1984 | T    N                 |    D     E     P U     |                        |                        |
1986 | T    N                 |  E D             PU    |                        |                        |
1988 | T    N             E   |     D             P U  |                        |                        |
1990 |  T   N      E          |     D              P U |                        |                        |
1992 |  T   N E               |      D               PU|                        |                        |
1994 |  T  EN                 |      D                P|U                       |                        |
1996 |  T  N                  |       D                |PU                      |                        | TE
1998 | ET  N                  |       D                | PU                     |                        |
2000 |E  T N                  |        D               |  P U                   |                        |
2002 E   T N                  |        D               |    PU                  |                        |
2004 E   T N                  |         D              |     PU                 |                        |
2006 E   T N                  |         D              |       PU               |                        |
2008 E    TN                  |          D             |        PU              |                        |
2010 E    TN                  |           D            |          PU            |                        |
2012 E    TN                  |           D            |            P           |                        | PU
2014 E     N                  |            D           |             PU         |                        | NT
2016 E     N                  |            D           |               PU       |                        | NT
2018 E    NT                  |             D          |                 P      |                        | PU
2020 E    N T                 |              D         |                  PU    |                        |
2022 E    N T                 |              D         |                    PU  |                        |
2024 E    N  T                |               D        |                      P |                        | PU
2026 E    N  T                |                D       |                       PU                        |

TIME 0    5    10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95   100       DUPLICATES
```

Figure 29d: Apocalyptic Scenario--NNP(N), Population(P), Disabled Population(D), Technology Ratio(T), Unemployment(U), Rehab Funds/Disabled Person(E)

Results from the Demographic Sector. In this sector, the dynamics produced by the demographic structure described in the previous section together with statistics specifying 1) the demography of the total population and 2) the prevalence of the various case study disability groups, are considered. The sector assumes

1) birth rate normal BRN, is zero for each of the disability groups,
2) accident rate frequencies are consistent with disabled population size, and
3) death rate frequencies are also proportional to size of the associated demographic group.

The results are depicted for the upper scenario only in Figures 30 (a, b, and c), 31 (a, b, and c), 32 (a, b, and c), and 33 (a, b, and c). Shown in these figures are demographic trees for the healthy population (Figure 30) and the following disability groups: mental retardation (Figure 31), hearing impairment (Figure 32), and schizophrenia (Figure 33). It should be observed that for the year 1940, all trees have exactly the same form. This is due to the use of the prevalence statistics to specify demographic sizes for the various age, sex, disability cohorts. However, for demonstration purposes (and in the absence of data) the birth rates for each of the disability groups is taken to be zero. Consequently, these groups exhibit populations which are aging. "Snapshots" are shown for the years 1940, 1980, and 2020 in parts a, b, and c of Figures 30, 31, 32, and 33. The snapshots for the years 1980 and 2020 clearly exhibit aging within the various groups, as cohort sizes in the low age groups decline.

The concept of aging disabled populations is easily corroborated by the rationale that society has greater economic incentive to rehabilitate younger persons, and is consistent with the fact that new medical technology is capable of extending the life of disabled persons through preventing deaths without actually ameliorating the disabling condition. Preventive medicine will also contribute to the aging disabled population phenomenon. The result is an increased burden upon supplemental income and transfer payment requirements. Bureaucratic institutions such as the Social Security Administration may not be able to accommodate all of the requests for supplemental income and medical payments.

Associated with each age cohort are two figures on the left and right margins. The "upper" of the two numbers is the fraction of males or females within that particular age group. The second or lower of the two numbers is the total number of such persons (in thousands) within the particular age, sex, and disability cohort. Thus there are 3,004,000 healthy males aged 50 through 54 and this represents .0568 of the healthy male population in the year 1940. In Figure 31b, we observe that there are 450,000 mentally retarded males aged 45 through 49 and that this represents .1045 of the mentally retarded male population. Thus roughly 10% of all mentally retarded males are aged 45 through 49 as shown in the figure. Each figure provides a snapshot of the age and sex distribution for a particular disability group at a specific instant in time.

The actual numbers printed in the margins are only ball park "guesstimates" of their actual real-world counterparts. They are not important; significant inroads to better understanding come from the general dynamics -- a disabled population which grows older.

Although trees for all fourteen case-study disability groups could have been included here for each of the years 1940, 1980, and 2020 (or for any year between 1940 and 2026 inclusive), it was felt that such inclusion would contribute very little to the behavioral results already depicted and described herein.

```
                            POPULATION TREE FOR CATEGORY 15 IN YEAR 1940.  NAME:HEALTHY
                            MALES                                                           FEMALES
         25%       20%       15%       10%        5%      0%  AGE   0%         5%       10%       15%       20%       25%
.0667000                                     <<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>                                       .0703000
 3527000                                     <<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>                                        3692000
.0363000                                           <<<<<<<|  60TO64  |>>>>>>>                                              .0355000
 1919000                                           <<<<<<<|  60TO64  |>>>>>>>                                               1865000
.0456000                                         <<<<<<<<<|  55TO59  |>>>>>>>>>           fraction of females aged 55-59   .0432000
 2410000                                         <<<<<<<<<|  55TO59  |>>>>>>>>>                   number of such females    2267000
.0568000                                       <<<<<<<<<<<|  50TO54  |>>>>>>>>>>>                                          .0534000
 3004000                                       <<<<<<<<<<<|  50TO54  |>>>>>>>>>>>                                           2805000
.0637000                                     <<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>                                         .0617000
 3369000                                     <<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>                                          3238000
.0669000                                     <<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>                                        .0666000
 3537000                                     <<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>                                         3497000
.0718000                                    <<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>                                      .0732000
 3799000                                    <<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>                                       3842000
.0768000                                   <<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>>                                     .0789000
 4058000                                   <<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>>                                      4140000
.0825000                                 <<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>>>                                    .0861000
 4363000                                 <<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>>>                                     4519000
.0862000                                 <<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>>                                   .0899000
 4556000                                 <<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>>                                    4719000
.0936000                               <<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>                                  .0938000
 4947000                               <<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>                                   4925000
.0901000                                <<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>                                   .0883000
 4764000                                <<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>                                    4637000
.0820000                                  <<<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>>>                                     .0803000
 4337000                                  <<<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>>>                                      4215000
.0811000    fraction of males in 0-5 group<<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>>>                                     .0791000
 4286000    number of such males          <<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>>>                                      4152000
         25%       20%       15%       10%        5%      0%  AGE   0%         5%       10%       15%       20%       25%
```

Figure 30a: Demographic Tree for Healthy Population in the Year 1940

```
                                   POPULATION TREE FOR CATEGORY 15 IN YEAR 1980.  NAME:HEALTHY
                                   MALES                                                          FEMALES
-------------------------------------------------------------------------------------------------------------------------
          25%       20%       15%       10%       5%       0%  AGE   0%         5%        10%       15%       20%       25%
 .0523000                                      <<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>                                  .0805000
  6014000                                      <<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>                                   9808000
 .0254000                                          <<<<<<<|  60TO64  |>>>>>>>                                            .0329000
  3173000                                          <<<<<<<|  60TO64  |>>>>>>>                                             4014000
 .0349000                                         <<<<<<<<|  55TO59  |>>>>>>>                                            .0372000
  4007000                                         <<<<<<<<|  55TO59  |>>>>>>>                                             4531000
 .0419000                                        <<<<<<<<<|  50TO54  |>>>>>>>>                                           .0424000
  4811000                                        <<<<<<<<<|  50TO54  |>>>>>>>>                                            5169000
 .0491000                                      <<<<<<<<<<<|  45TO49  |>>>>>>>>>>                                         .0478000
  5524000                                      <<<<<<<<<<<|  45TO49  |>>>>>>>>>>                                          5821000
 .0557000                                     <<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>                                        .0544000
  6404000                                     <<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>                                         6627000
 .0634000                                   <<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>                                       .0615000
  7279000                                   <<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>                                        7490000
 .0719000                                  <<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>                                     .0694000
  8259000                                  <<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>                                      8454000
 .0903000                                <<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>                                    .0773000
  9226000                                <<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>                                     9415000
 .0889000                              <<<<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>                                  .0851000
 10202000                              <<<<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>                                  10370000
 .0970000                             <<<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>                                .0926000
 11149000                             <<<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>                                11281000
 .1051000                           <<<<<<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>>>                               .0958000
 12079000                           <<<<<<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>>>                               12160000
 .1123000                          <<<<<<<<<<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>>>>>>>>                              .1065000
 12903000                          <<<<<<<<<<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>>>>>>>>                              12980000
 .1189000                        <<<<<<<<<<<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>>>>>>>>>>                            .1126000
 13655000                        <<<<<<<<<<<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>>>>>>>>>>                            13724000
----------25%-------20%-------15%-------10%-------5%-------0%--AGE---0%---------5%--------10%-------15%-------20%-------25%------
```

Figure 30b: Demographic Tree for Healthy Population in Year 1980

1-85

```
                                   POPULATION TREE FOR CATEGORY 15 IN YEAR 2020.  NAME:HEALTHY
                                   MALES                                                                  FEMALES
          25%      20%      15%      10%      5%        0%  AGE     0%        5%       10%      15%      20%      25%
 .0768000                              <<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>                          .1165000
 12604000                              <<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>                          20983000
 .0450000                                    <<<<<<<<<|  60TO64  |>>>>>>>>>>                                       .0495000
  7387000                                    <<<<<<<<<|  60TO64  |>>>>>>>>>>                                        8971000
 .0533000                                  <<<<<<<<<<<|  55TO59  |>>>>>>>>>>>                                      .0558000
  8739000                                  <<<<<<<<<<<|  55TO59  |>>>>>>>>>>>                                       9953000
 .0625000                                <<<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>>                                     .0623000
 10256000                                <<<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>>                                     11159000
 .0686000                               <<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>>                                    .0670000
 11255000                               <<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>>                                    12016000
 .0744000                              <<<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>>                                   .0713000
 12204000                              <<<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>>                                   12778000
 .0775000                              <<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>                                  .0737000
 12707000                              <<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>                                  13209000
 .0793000                             <<<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>                                  .0749000
 13011000                             <<<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>                                  13421000
 .0791000                             <<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>                                  .0743000
 12984000                             <<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>                                  13320000
 .0780000                             <<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>                                  .0728000
 12791000                             <<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>                                  13047000
 .0764000                              <<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>                                   .0709000
 12541000                              <<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>                                   12714000
 .0757000                              <<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>                                   .0698000
 12418000                              <<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>                                   12511000
 .0759000                              <<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>                                   .0699000
 12449000                              <<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>                                   12528000
 .0775000                             <<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>                                   .0713000
 12719000                             <<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>                                   12786000
          25%      20%      15%      10%      5%        0%  AGE     0%        5%       10%      15%      20%      25%
```

Figure 30c: Demographic Tree for Healthy Population in Year 2020

```
                                        POPULATION TREE FOR CATEGORY  8 IN YEAR 1940.  NAME:MENTAL RETARDATION
                                        MALES                                                            FEMALES
           25%        20%        15%        10%        5%      0%  AGE    0%        5%        10%       15%       20%       25%
  .0667000                                   <<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>                                             .0703000
     88000                                   <<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>                                                92000
  .0363000                                          <<<<<<<<|  60TO64  |>>>>>>>>                                                     .0355000
     48000                                          <<<<<<<<|  60TO64  |>>>>>>>>                                                        47000
  .0455000                                        <<<<<<<<<<|  55TO59  |>>>>>>>>>>                                                   .0432000
     60000                                         <<<<<<<<<|  55TO59  |>>>>>>>>>>                                                      57000
  .0564000                                     <<<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>>                                                 .0534000
     75000                                      <<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>>                                                    70000
  .0637000                                   <<<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>>>                                               .0617000
     84000                                   <<<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>>>                                                  81000
  .0669000                                   <<<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>>>                                              .0666000
     88000                                  <<<<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>>>                                                 87000
  .0718000                                  <<<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>>>                                            .0732000
     95000                                  <<<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>>>                                               96000
  .0768000                                <<<<<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>>>>                                           .0788000
    101000                                 <<<<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>>>>                                             103000
  .0825000                               <<<<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>>>>>                                          .0861000
    109000                               <<<<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>>>>>                                            113000
  .0862000                               <<<<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>>>>                                         .0899000
    114000                               <<<<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>>>>                                           118000
  .0936000                            <<<<<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>>>                                        .0938000
    124000                             <<<<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>>>                                          123000
  .0901000                             <<<<<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>>>                                         .0883000
    119000                             <<<<<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>>>                                           116000
  .0820000                                <<<<<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>>>>>                                           .0803000
    108000                                <<<<<<<<<<<<<<<<<<|   5TO 9  |>>>>>>>>>>>>>>>>>>                                             105000
  .0811000                                <<<<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>>>>>                                           .0791000
    107000                                <<<<<<<<<<<<<<<<<<|   0TO 5  |>>>>>>>>>>>>>>>>>>                                             104000
___________25%________20%________15%________10%________5%______0%__AGE____0%________5%________10%_______15%_______20%_______25%______
```

Figure 31a: Demographic Tree for Mental Retardation in Year 1940

```
                                        POPULATION TREE FOR CATEGORY  8 IN YEAR 1980.  NAME:MENTAL RETARDATION
                                        MALES                                                              FEMALES
            25%        20%        15%        10%         5%        0%  AGE    0%         5%         10%        15%        20%        25%
  .2479000 <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>.3294000
    137000 <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>   229000
  .1195000                             <<<<<<<<<<<<<<<<<<<<<<<<<<| 60TO64 |>>>>>>>>>>>>>>>>>>>>>>>>>>                                   .1173000
     67000                             <<<<<<<<<<<<<<<<<<<<<<<<<<| 60TO64 |>>>>>>>>>>>>>>>>>>>>>>>>>>                                      81000
  .1254000                           <<<<<<<<<<<<<<<<<<<<<<<<<<<<| 55TO59 |>>>>>>>>>>>>>>>>>>>>>>>>>>                                   .1170000
     71000                           <<<<<<<<<<<<<<<<<<<<<<<<<<<<| 55TO59 |>>>>>>>>>>>>>>>>>>>>>>>>>>                                      81000
  .1258000                           <<<<<<<<<<<<<<<<<<<<<<<<<<<<| 50TO54 |>>>>>>>>>>>>>>>>>>>>>>>>>                                    .1119000
     72000                           <<<<<<<<<<<<<<<<<<<<<<<<<<<<| 50TO54 |>>>>>>>>>>>>>>>>>>>>>>>>>                                       78000
  .1141000                             <<<<<<<<<<<<<<<<<<<<<<<<<<| 45TO49 |>>>>>>>>>>>>>>>>>>>>>>>                                      .0985000
     64000                             <<<<<<<<<<<<<<<<<<<<<<<<<<| 45TO49 |>>>>>>>>>>>>>>>>>>>>>>>                                         68000
  .0563000                                  <<<<<<<<<<<<<<<<<<<<<| 40TO44 |>>>>>>>>>>>>>>>>>>                                           .0811000
     54000                                  <<<<<<<<<<<<<<<<<<<<<| 40TO44 |>>>>>>>>>>>>>>>>>>                                              56000
  .0725000                                       <<<<<<<<<<<<<<<<| 35TO39 |>>>>>>>>>>>>>>                                               .0605000
     41000                                       <<<<<<<<<<<<<<<<| 35TO39 |>>>>>>>>>>>>>>                                                  42000
  .0494000                                            <<<<<<<<<<<| 30TO34 |>>>>>>>>>                                                    .0409000
     28000                                            <<<<<<<<<<<| 30TO34 |>>>>>>>>>                                                       28000
  .0294000                                                 <<<<<<| 25TO29 |>>>>>                                                        .0241000
     17000                                                 <<<<<<| 25TO29 |>>>>>                                                           17000
  .0150000                                                    <<<| 20TO24 |>>                                                           .0122000
      8000                                                    <<<| 20TO24 |>>                                                               8000
  .0062000                                                      <| 15TO19 |>                                                            .0050000
      4000                                                      <| 15TO19 |>                                                                4000
  .0020000                                                       | 10TO14 |                                                             .0016000
      1000                                                       | 10TO14 |                                                                 1000
  .0004000                                                       |  5TO 9 |                                                             .0003000
      0000                                                       |  5TO 9 |                                                                 0000
  .0000000                                                       |  0TO 5 |                                                             .0000000
      0000                                                       |  0TO 5 |                                                                 0000
            25%        20%        15%        10%         5%        0%  AGE    0%         5%         10%        15%        20%        25%
```

Figure 31b: Demographic Tree for Mental Retardation in Year 1980

```
                                  POPULATION TREE FOR CATEGORY  8  IN YEAR  2020.  NAME:MENTAL RETARDATION
                                  MALES                                                             FEMALES
        25%       20%       15%       10%       5%       0%  AGE    0%       5%       10%       15%       20%       25%
.6178000<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>.7530000
   41000<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>    99000
.1378000                                <<<<<<<<<<<<<<<<<<<<<<<<<<<<| 60TO64 |>>>>>>>>>>>>>>>>>>                                              .0924000
    9000                                <<<<<<<<<<<<<<<<<<<<<<<<<<<<| 60TO64 |>>>>>>>>>>>>>>>>>>                                                 12000
.1001000                                        <<<<<<<<<<<<<<<<<<<<| 55TO59 |>>>>>>>>>>>>>                                                   .0628000
    7000                                        <<<<<<<<<<<<<<<<<<<<| 55TO59 |>>>>>>>>>>>>>                                                       8000
.0687000                                              <<<<<<<<<<<<<<| 50TO54 |>>>>>>>>                                                        .0399000
    5000                                              <<<<<<<<<<<<<<| 50TO54 |>>>>>>>>                                                            5000
.0396000                                                    <<<<<<<<| 45TO49 |>>>>                                                            .0224000
    3000                                                    <<<<<<<<| 45TO49 |>>>>                                                                3000
.0210000                                                        <<<<| 40TO44 |>>                                                              .0115000
    1000                                                        <<<<| 40TO44 |>>                                                                  1000
.0095000                                                          <<| 35TO39 |>                                                               .0052000
    1000                                                          <<| 35TO39 |>                                                                   1000
.0038000                                                           <| 30TO34 |                                                                .0020000
    0000                                                           <| 30TO34 |                                                                    0000
.0013000                                                            | 25TO29 |                                                                .0007000
    0000                                                            | 25TO29 |                                                                    0000
.0006000                                                            | 20TO24 |                                                                .0002000
    0000                                                            | 20TO24 |                                                                    0000
.0001000                                                            | 15TO19 |                                                                .0000000
    0000                                                            | 15TO19 |                                                                    0000
.0000000                                                            | 10TO14 |                                                                .0000000
    0000                                                            | 10TO14 |                                                                    0000
.0000000                                                            |  5TO 9 |                                                                .0000000
    0000                                                            |  5TO 9 |                                                                    0000
.0000000                                                            |  0TO 5 |                                                                .0000000
    0000                                                            |  0TO 5 |                                                                    0000
        25%       20%       15%       10%       5%       0%  AGE    0%       5%       10%       15%       20%       25%
```

Figure 31c: Demographic Tree for Mental Retardation in Year 2020

```
                                    POPULATION TREE FOR CATEGORY 14 IN YEAR 1940.  NAME:HEARING IMPAIRMENT
                                    MALES                                                          FEMALES
          25%       20%       15%       10%        5%          0%  AGE   0%        5%        10%       15%       20%       25%
.0667000                                      <<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>                                        .0703000
  291000                                      <<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>                                          304000
.0343000                                            <<<<<<<<|  60TO64  |>>>>>>>                                               .0355000
  158000                                            <<<<<<<<|  60TO64  |>>>>>>>                                                 154000
.0456000                                          <<<<<<<<<<|  55TO59  |>>>>>>>>>                                             .0432000
  199000                                          <<<<<<<<<<|  55TO59  |>>>>>>>>>                                               187000
.0568000                                        <<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>                                           .0534000
  249000                                        <<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>                                             231000
.0637000                                      <<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>                                          .0617000
  278000                                      <<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>                                            267000
.0669000                                      <<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>                                         .0566000
  292000                                      <<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>                                           288000
.0713000                                     <<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>                                       .0732000
  313000                                     <<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>>>>                                         317000
.0768000                                    <<<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>>                                      .0788000
  335000                                    <<<<<<<<<<<<<<<<|  30TO34  |>>>>>>>>>>>>>>>>                                        341000
.0825000                                  <<<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>>>                                     .0861000
  360000                                  <<<<<<<<<<<<<<<<<<|  25TO29  |>>>>>>>>>>>>>>>>>                                       373000
.0862000                                  <<<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>>                                    .0899000
  376000                                  <<<<<<<<<<<<<<<<<<|  20TO24  |>>>>>>>>>>>>>>>>>>                                      389000
.0936000                                <<<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>                                   .0938000
  408000                                <<<<<<<<<<<<<<<<<<<<|  15TO19  |>>>>>>>>>>>>>>>>>>>                                     406000
.0901000                                 <<<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>                                    .0883000
  393000                                 <<<<<<<<<<<<<<<<<<<|  10TO14  |>>>>>>>>>>>>>>>>>>                                      382000
.0820000                                   <<<<<<<<<<<<<<<<<|  5TO 9   |>>>>>>>>>>>>>>>>                                      .0803000
  353000                                   <<<<<<<<<<<<<<<<<|  5TO 9   |>>>>>>>>>>>>>>>>                                        348000
.0811000                                   <<<<<<<<<<<<<<<<<|  0TO 5   |>>>>>>>>>>>>>>>>                                      .0791000
  353000                                   <<<<<<<<<<<<<<<<<|  0TO 5   |>>>>>>>>>>>>>>>>                                        342000
          25%       20%       15%       10%        5%          0%  AGE   0%        5%        10%       15%       20%       25%
```

Figure 32a: Demographic Tree for hearing Impairment in Year 1940

```
                               POPULATION TREE FOR CATEGORY 14 IN YEAR 1980.  NAME:HEARING IMPAIRMENT
                               MALES                                                     FEMALES
          25%       20%       15%       10%       5%      0%  AGE    0%      5%       10%       15%       20%       25%
.2429000 <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>.3294000
  453000 <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>> 759000
.1195000                          <<<<<<<<<<<<<<<<<<<<<<<<| 60TO64  |>>>>>>>>>>>>>>>>>>>>>>>                               .1173000
  223000                          <<<<<<<<<<<<<<<<<<<<<<<<| 60TO64  |>>>>>>>>>>>>>>>>>>>>>>>                                 269000
.1254000                         <<<<<<<<<<<<<<<<<<<<<<<<<| 55TO59  |>>>>>>>>>>>>>>>>>>>>>>>                               .1170000
  234000                         <<<<<<<<<<<<<<<<<<<<<<<<<| 55TO59  |>>>>>>>>>>>>>>>>>>>>>>>                                 268000
.1269000                         <<<<<<<<<<<<<<<<<<<<<<<<<| 50TO54  |>>>>>>>>>>>>>>>>>>>>>>                                .1119000
  236000                         <<<<<<<<<<<<<<<<<<<<<<<<<| 50TO54  |>>>>>>>>>>>>>>>>>>>>>>                                  255000
.1141000                           <<<<<<<<<<<<<<<<<<<<<<<| 45TO49  |>>>>>>>>>>>>>>>>>>>>                                  .0985000
  213000                           <<<<<<<<<<<<<<<<<<<<<<<| 45TO49  |>>>>>>>>>>>>>>>>>>>>                                    226000
.0983000                               <<<<<<<<<<<<<<<<<<<| 40TO44  |>>>>>>>>>>>>>>>>                                      .0811000
  179000                               <<<<<<<<<<<<<<<<<<<| 40TO44  |>>>>>>>>>>>>>>>>                                        186000
.0725000                                   <<<<<<<<<<<<<<<| 35TO39  |>>>>>>>>>>>>                                          .0605000
  135000                                   <<<<<<<<<<<<<<<| 35TO39  |>>>>>>>>>>>>.                                         139000
.0454000                                        <<<<<<<<<<| 30TO34  |>>>>>>>>                                              .0408000
   92000                                        <<<<<<<<<<| 30TO34  |>>>>>>>>                                                94000
.0284000                                            <<<<<<| 25TO29  |>>>>>                                                 .0241000
   55000                                            <<<<<<| 25TO29  |>>>>>                                                   55000
.0150000                                               <<<| 20TO24  |>>                                                    .0122000
   28000                                               <<<| 20TO24  |>>                                                      28000
.0062000                                                 <| 15TO19  |>                                                     .0050000
   12000                                                 <| 15TO19  |>                                                       12000
.0020000                                                  | 10TO14  |                                                      .0016000
    4000                                                  | 10TO14  |                                                         4000
.0004000                                                  |  5TO 9  |                                                      .0003000
    1000                                                  |  5TO 9  |                                                         1000
.0000000                                                  |  0TO 5  |                                                      .0000000
    0000                                                  |  0TO 5  |                                                         0000
          25%       20%       15%       10%       5%      0%  AGE    0%      5%       10%       15%       20%       25%
```

Figure 32b: Demographic Tree for Hearing Impairment in Year 1980

```
                              POPULATION TREE FOR CATEGORY 14 IN YEAR 2020.  NAME:HEARING IMPAIRMENT
                              MALES                                                       FEMALES
          25%       20%       15%       10%       5%       0%  AGE     0%       5%       10%       15%       20%       25%
 .6178000<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>.7630000
   136000<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>  328000
 .1378000                             <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<|  60TO64  |>>>>>>>>>>>>>>>>>>>>>>>                                             .0924000
    30000                             <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<|  60TO64  |>>>>>>>>>>>>>>>>>>>>>>>                                                40000
 .1001000                                        <<<<<<<<<<<<<<<<<<<<<<<<|  55TO59  |>>>>>>>>>>>>>>>>>                                                   .0628000
    22000                                        <<<<<<<<<<<<<<<<<<<<<<<<|  55TO59  |>>>>>>>>>>>>>>>>>                                                      27000
 .0687000                                              <<<<<<<<<<<<<<<<<<|  50TO54  |>>>>>>>>>                                                           .0399000
    15000                                              <<<<<<<<<<<<<<<<<<|  50TO54  |>>>>>>>>>                                                              17000
 .0396000                                                       <<<<<<<<<|  45TO49  |>>>>>                                                               .0224000
     9000                                                       <<<<<<<<<|  45TO49  |>>>>>                                                                  10000
 .0210000                                                            <<<<|  40TO44  |>>                                                                  .0115000
     5000                                                            <<<<|  40TO44  |>>                                                                      5000
 .0095000                                                              <<|  35TO39  |>                                                                   .0052000
     2000                                                              <<|  35TO39  |>                                                                      2000
 .0039000                                                               <|  30TO34  |                                                                    .0020000
     1000                                                               <|  30TO34  |                                                                       1000
 .0013000                                                                |  25TO29  |                                                                    .0007000
     0000                                                                |  25TO29  |                                                                       0000
 .0004000                                                                |  20TO24  |                                                                    .0002000
     0000                                                                |  20TO24  |                                                                       0000
 .0001000                                                                |  15TO19  |                                                                    .0000000
     0000                                                                |  15TO19  |                                                                       0000
 .0000300                                                                |  10TO14  |                                                                    .0000000
     0000                                                                |  10TO14  |                                                                       0000
 .0000000                                                                |   5TO 9  |                                                                    .0000000
     0000                                                                |   5TO 9  |                                                                       0000
 .0000000                                                                |   0TO 5  |                                                                    .0000000
     0000                                                                |   0TO 5  |                                                                       0000
          25%       20%       15%       10%       5%       0%  AGE     0%       5%       10%       15%       20%       25%
```

Figure 32c: Demographic Tree for Hearing Impairment in Year 2020

```
                            POPULATION TREE FOR CATEGORY  7 IN YEAR 1940.  NAME:SCHIZOPHRENIA
                            MALES                                                           FEMALES
___________25%_______20%_______15%_______10%_______5%_______0% AGE  0%_______5%_______10%_______15%_______20%_______25%__________
 .0667000                                   <<<<<<<<<<<<<<<| 65TOUP |>>>>>>>>>>>>>>>                                  .0703000
   132000                                   <<<<<<<<<<<<<<<| 65TOUP |>>>>>>>>>>>>>>>                                    138000
 .0363000                                          <<<<<<<<| 60TO64 |>>>>>>>>                                         .0355000
    72000                                          <<<<<<<<| 60TO64 |>>>>>>>>                                            70000
 .0456000                                        <<<<<<<<<<| 55TO59 |>>>>>>>>>>                                       .0432000
    90000                                        <<<<<<<<<<| 55TO59 |>>>>>>>>>>                                          85000
 .0568000                                     <<<<<<<<<<<<<| 50TO54 |>>>>>>>>>>>>                                     .0534000
   113000                                     <<<<<<<<<<<<<| 50TO54 |>>>>>>>>>>>>                                       105000
 .0637000                                   <<<<<<<<<<<<<<<| 45TO49 |>>>>>>>>>>>>>                                    .0617000
   126000                                   <<<<<<<<<<<<<<<| 45TO49 |>>>>>>>>>>>>>                                      121000
 .0669000                                   <<<<<<<<<<<<<<<| 40TO44 |>>>>>>>>>>>>>>                                   .0666000
   133000                                   <<<<<<<<<<<<<<<| 40TO44 |>>>>>>>>>>>>>>                                     131000
 .0718000                                  <<<<<<<<<<<<<<<<| 35TO39 |>>>>>>>>>>>>>>>>                                 .0732000
   142000                                  <<<<<<<<<<<<<<<<| 35TO39 |>>>>>>>>>>>>>>>>                                   144000
 .0769000                                 <<<<<<<<<<<<<<<<<| 30TO34 |>>>>>>>>>>>>>>>>>                                .0788000
   152000                                 <<<<<<<<<<<<<<<<<| 30TO34 |>>>>>>>>>>>>>>>>>                                  155000
 .0825000                               <<<<<<<<<<<<<<<<<<<| 25TO29 |>>>>>>>>>>>>>>>>>>>                              .0861000
   164000                               <<<<<<<<<<<<<<<<<<<| 25TO29 |>>>>>>>>>>>>>>>>>>>                                169000
 .0862000                               <<<<<<<<<<<<<<<<<<<| 20TO24 |>>>>>>>>>>>>>>>>>>>>                             .0899000
   171000                               <<<<<<<<<<<<<<<<<<<| 20TO24 |>>>>>>>>>>>>>>>>>>>>                               177000
 .0936000                             <<<<<<<<<<<<<<<<<<<<<| 15TO19 |>>>>>>>>>>>>>>>>>>>>>                            .0938000
   185000                             <<<<<<<<<<<<<<<<<<<<<| 15TO19 |>>>>>>>>>>>>>>>>>>>>>                              185000
 .0901000                              <<<<<<<<<<<<<<<<<<<<| 10TO14 |>>>>>>>>>>>>>>>>>>>>                             .0883000
   179000                              <<<<<<<<<<<<<<<<<<<<| 10TO14 |>>>>>>>>>>>>>>>>>>>>                               174000
 .0820000                                <<<<<<<<<<<<<<<<<<|  5TO 9 |>>>>>>>>>>>>>>>>>                                .0803000
   163000                                <<<<<<<<<<<<<<<<<<|  5TO 9 |>>>>>>>>>>>>>>>>>                                  158000
 .0811000                                <<<<<<<<<<<<<<<<<<|  0TO 5 |>>>>>>>>>>>>>>>>>>                               .0791000
   161000                                <<<<<<<<<<<<<<<<<<|  0TO 5 |>>>>>>>>>>>>>>>>>>                                 156000
___________25%_______20%_______15%_______10%_______5%_______0% AGE  0%_______5%_______10%_______15%_______20%_______25%__________
```

Figure 33a: Demographic Tree for Schizophrenia in Year 1940

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```
                                    POPULATION TREE FOR CATEGORY  7 IN YEAR 1980.  NAME:SCHIZOPHRENIA
                                    MALES                                                              FEMALES
         25%       20%       15%       10%       5%        0%  AGE    0%        5%        10%       15%       20%       25%
.2429000  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>.3294000
  206000  <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<|  65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>   343000
.1195000                           <<<<<<<<<<<<<<<<<<<<<<<<|  60TO64  |>>>>>>>>>>>>>>>>>>>>>>>                               .1173000
  101000                           <<<<<<<<<<<<<<<<<<<<<<<<|  60TO64  |>>>>>>>>>>>>>>>>>>>>>>>                                 122000
.1254000                          <<<<<<<<<<<<<<<<<<<<<<<<<|  55TO59  |>>>>>>>>>>>>>>>>>>>>>>>                               .1170000
  105000                          <<<<<<<<<<<<<<<<<<<<<<<<<|  55TO59  |>>>>>>>>>>>>>>>>>>>>>>>                                 122000
.1268000                          <<<<<<<<<<<<<<<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>>>>>>>>>>>>                                .1119000
  107000                          <<<<<<<<<<<<<<<<<<<<<<<<<|  50TO54  |>>>>>>>>>>>>>>>>>>>>>>                                  117000
.1141000                            <<<<<<<<<<<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>>>>>>>>>                                  .0985000
   97000                            <<<<<<<<<<<<<<<<<<<<<<<|  45TO49  |>>>>>>>>>>>>>>>>>>>>                                    103000
.0963000                                <<<<<<<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>>>>                                      .0811000
   82000                                <<<<<<<<<<<<<<<<<<<|  40TO44  |>>>>>>>>>>>>>>>>                                         84000
.0725000                                    <<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>                                          .0605000
   61000                                    <<<<<<<<<<<<<<<|  35TO39  |>>>>>>>>>>>>                                             63000
.0494000                                         <<<<<<<<<<|  30TO34  |>>>>>>>>                                              .0408000
   42000                                         <<<<<<<<<<|  30TO34  |>>>>>>>>                                                 43000
.0294000                                             <<<<<<|  25TO29  |>>>>>                                                 .0241000
   25000                                             <<<<<<|  25TO29  |>>>>>                                                    25000
.0150000                                                <<<|  20TO24  |>>                                                    .0122000
   13000                                                <<<|  20TO24  |>>                                                       13000
.0062000                                                  <|  15TO19  |>                                                     .0050000
    5000                                                  <|  15TO19  |>                                                         5000
.0020000                                                   |  10TO14  |                                                      .0016000
    2000                                                   |  10TO14  |                                                          2000
.0004000                                                   |   5TO 9  |                                                      .0003000
    0000                                                   |   5TO 9  |                                                          0000
.0000000                                                   |   0TO 5  |                                                      .0000000
    0000                                                   |   0TO 5  |                                                          0000
         25%       20%       15%       10%       5%        0%  AGE    0%        5%        10%       15%       20%       25%
```

Figure 33b: Demographic Tree for Schizophrenia in Year 1980

```
                                       POPULATION TREE FOR CATEGORY  7 IN YEAR 2020.  NAME:SCHIZOPHRENIA
                                       MALES                                                                          FEMALES
            25%         20%         15%         10%          5%         0%   AGE    0%          5%         10%         15%         20%         25%
 .6173000<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>  .7630000
    62000<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 65TOUP  |>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>    149000
 .1378000                           <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 60TO64  |>>>>>>>>>>>>>>>>>>>>>>                                             .0924000
    14000                           <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<| 60TO64  |>>>>>>>>>>>>>>>>>>>>>>                                                18000
 .1001000                                     <<<<<<<<<<<<<<<<<<<<<<<<| 55TO59  |>>>>>>>>>>>>>>>                                                    .0628000
    10000                                     <<<<<<<<<<<<<<<<<<<<<<<<| 55TO59  |>>>>>>>>>>>>>>>                                                       12000
 .0697000                                            <<<<<<<<<<<<<<<<<| 50TO54  |>>>>>>>>>                                                          .0359000
     7000                                            <<<<<<<<<<<<<<<<<| 50TO54  |>>>>>>>>>                                                              8000
 .0355000                                                    <<<<<<<<<| 45TO49  |>>>>                                                               .0224000
     4000                                                    <<<<<<<<<| 45TO49  |>>>>                                                                   4000
 .0210000                                                         <<<<| 40TO44  |>>                                                                 .0115000
     2000                                                         <<<<| 40TO44  |>>                                                                     2000
 .0055000                                                           <<| 35TO39  |>                                                                  .0052000
     1000                                                           <<| 35TO39  |>                                                                      1000
 .0038000                                                            <| 30TO34  |                                                                   .0020000
     0000                                                            <| 30TO34  |                                                                       0000
 .0013000                                                             | 25TO29  |                                                                   .0007000
     0000                                                             | 25TO29  |                                                                       0000
 .0004000                                                             | 20TO24  |                                                                   .0002000
     0000                                                             | 20TO24  |                                                                       0000
 .0001000                                                             | 15TO19  |                                                                   .0000000
     0000                                                             | 15TO19  |                                                                       0000
 .0000000                                                             | 10TO14  |                                                                   .0000000
     0000                                                             | 10TO14  |                                                                       0000
 .0000000                                                             |  5TO 9  |                                                                   .0000000
     0000                                                             |  5TO 9  |                                                                       0000
 .0000000                                                             |  0TO 5  |                                                                   .0000000
     0000                                                             |  0TO 5  |                                                                       0000
            25%         20%         15%         10%          5%         0%   AGE    0%          5%         10%         15%         20%         25%
```

Figure 33c: Demographic Tree for Schizophrenia in Year 2020

Results from the Technology and Life-Functions Sectors. Since the rehabilitation technology sector, as previously described, is a subsector of the life-functions sector, it has no internal dynamics intrinsically its own that need be displayed or discussed. Its behavior is dependent upon program sector funding and technological growth.

The life-function sector produces results shown in Figure 34. A monotonically improving upward trend is observed for scenarios M and U whereas the life-functions tend to improve for the simulated years 1940 to 1976 after which a decline is observed to the year 2025 in scenarios L and A.

Results from the Program Sector. This sector allocates the funds available for rehabilitation to the various technology groups -- physical intervention, environmental change, training and counseling, and service delivery -- using the structure depicted in Figure 25. The following fractions are used in the results depicted in Figure 35 (a, b, c, and d):

physical intervention: .35
training and counseling: .30
environmental change: .20
service delivery: .15
Policy P

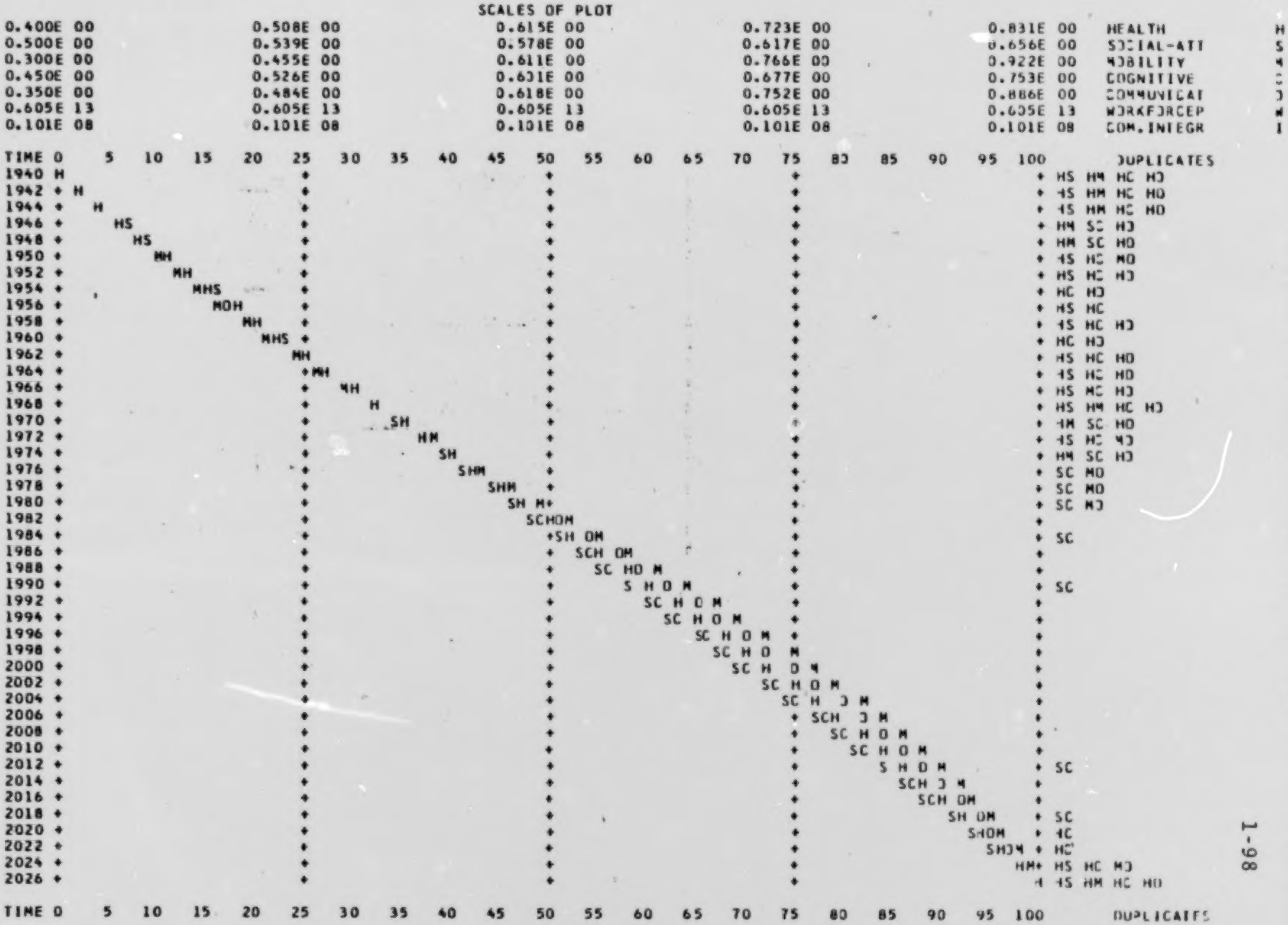
In Figure 35 are plotted the following quantities: physical intervention funds, environmental change funds, training and counseling funds, service delivery funds, transfer payments, medical payments, total costs, and disabled income. In every case the units employed are dollars per year. Every variable shows a general exponential rise in Figure 35a when driven by the medial scenario. The exponential rise is to even higher levels in Figure 35b where the upper scenario

```
                                                SCALES OF PLOT
0.400E 00                0.508E 00                0.615E 00                0.723E 00                0.831E 00   HEALTH            H
0.500E 00                0.539E 00                0.578E 00                0.517E 00                0.556E 00   SOCIAL-ATT        S
0.300E 00                0.455E 00                0.611E 00                0.766E 00                0.922E 00   MOBILITY          M
0.450E 00                0.526E 00                0.601E 00                0.677E 00                0.753E 00   COGNITIVE         C
0.350E 00                0.484E 00                0.618E 00                0.752E 00                0.886E 00   COMMUNICAT        O
0.605E 13                0.605E 13                0.605E 13                0.605E 13                0.605E 13   WORKFORCEP        W
0.101E 08                0.101E 08                0.101E 08                0.101E 08                0.101E 08   COM.INTEGR        I

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95   100       DUPLICATES
1940 H                        +                        +                        +                        + HS HM HC HO
1942 + H                      +                        +                        +                        + HS HM HC HO
1944 +   H                    +                        +                        +                        + HS HM HC HO
1946 +     HS                 +                        +                        +                        + HM SC HO
1948 +       HS               +                        +                        +                        + HM SC HO
1950 +         MH             +                        +                        +                        + HS HC MO
1952 +           MH           +                        +                        +                        + HS HC HO
1954 +             MHS        +                        +                        +                        + HC HO
1956 +               MOH      +                        +                        +                        + HS HC
1958 +                  MH    +                        +                        +                        + HS HC HO
1960 +                    MHS +                        +                        +                        + HC HO
1962 +                       MH                        +                        +                        + HS HC HO
1964 +                        +MH                      +                        +                        + HS HC HO
1966 +                        +   MH                   +                        +                        + HS MC HO
1968 +                        +      H                 +                        +                        + HS HM HC HO
1970 +                        +        SH              +                        +                        + HM SC HO
1972 +                        +           HM           +                        +                        + HS HC MO
1974 +                        +             SH         +                        +                        + HM SC HO
1976 +                        +               SHM      +                        +                        + SC MO
1978 +                        +                  SHM   +                        +                        + SC MO
1980 +                        +                    SH M+                        +                        + SC MO
1982 +                        +                      SCHOM                      +                        +
1984 +                        +                        +SH OM                   +                        + SC
1986 +                        +                        +  SCH OM                +                        +
1988 +                        +                        +    SC HO M             +                        +
1990 +                        +                        +       S H O M          +                        + SC
1992 +                        +                        +         SC H O M       +                        +
1994 +                        +                        +           SC H O M     +                        +
1996 +                        +                        +              SC H O M  +                        +
1998 +                        +                        +                SC H O  M                        +
2000 +                        +                        +                  SC H  O M                      +
2002 +                        +                        +                     SC H O M                    +
2004 +                        +                        +                       SC H  O M                 +
2006 +                        +                        +                        + SCH  O M               +
2008 +                        +                        +                        +   SC H O M             +
2010 +                        +                        +                        +     SC H O M           +
2012 +                        +                        +                        +        S H O M         + SC
2014 +                        +                        +                        +          SCH O M       +
2016 +                        +                        +                        +            SCH OM      +
2018 +                        +                        +                        +               SH OM    + SC
2020 +                        +                        +                        +                 SHOM   + HC
2022 +                        +                        +                        +                   SHOM + HC
2024 +                        +                        +                        +                      HM+ HS HC MO
2026 +                        +                        +                        +                        H HS HM HC HO

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95   100       DUPLICATES
```

Figure 34a: Life-function Behavior in Response to Scenario M, Policy P: Health (H), Social-attitudinal (S), Mobility (M), Cognitive-intellectual (C), Communication (O)



```
                                                SCALES OF PLOT
0.400E 00                0.508E 00                0.615E 00                0.723E 00                0.831E 00   HEALTH           H
0.500E 00                0.539E 00                0.578E 00                0.617E 00                0.656E 00   SOCIAL-ATT       S
0.300E 00                0.455E 00                0.611E 00                0.766E 00                0.922E 00   MOBILITY         M
0.450E 00                0.526E 00                0.631E 00                0.677E 00                0.753E 00   COGNITIVE        C
0.350E 00                0.484E 00                0.618E 00                0.752E 00                0.886E 00   COMMUNICAT       O
0.605E 13                0.605E 13                0.605E 13                0.605E 13                0.605E 13   WORKFORCEP       W
0.101E 08                0.101E 08                0.101E 08                0.101E 08                0.101E 08   COM.INTEGR       I

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100      DUPLICATES
1940 H                        +                        +                        +                        + HS HM HC HO
1942 + H                      +                        +                        +                        + HS HM HC HO
1944 +   H                    +                        +                        +                        + HS HM HC HO
1946 +     HS                 +                        +                        +                        + HM SC HO
1948 +       HS               +                        +                        +                        + HM SC HO
1950 +         MH             +                        +                        +                        + HS HC MO
1952 +           MH           +                        +                        +                        + HS HC HO
1954 +             MHS        +                        +                        +                        + HC HO
1956 +               MOH      +                        +                        +                        + HS HC
1958 +                  MH    +                        +                        +                        + HS HC HO
1960 +                    MHS +                        +                        +                        + HC HO
1962 +                       MH                        +                        +                        + HS HC HO
1964 +                        +MH                      +                        +                        + HS HC HO
1966 +                        +   MH                   +                        +                        + HS MC HO
1968 +                        +      H                 +                        +                        + HS HM HC HO
1970 +                        +        SH              +                        +                        + HM SC HO
1972 +                        +           HM           +                        +                        + HS HC MO
1974 +                        +             SH         +                        +                        + HM SC HO
1976 +                        +               SHM      +                        +                        + SC MO
1978 +                        +                  SHM   +                        +                        + SC MO
1980 +                        +                    SH M+                        +                        + SC MO
1982 +                        +                      SCHOM                      +                        +
1984 +                        +                        +SH OM                   +                        + SC
1986 +                        +                        +  SCH OM                +                        +
1988 +                        +                        +    SC HO M             +                        +
1990 +                        +                        +       S H O M          +                        + SC
1992 +                        +                        +         SC H O M       +                        +
1994 +                        +                        +           SC H O M     +                        +
1996 +                        +                        +              SC H O M  +                        +
1998 +                        +                        +                SC H O  M                        +
2000 +                        +                        +                  SC H  O M                      +
2002 +                        +                        +                     SC H O M                    +
2004 +                        +                        +                       SC H  O M                 +
2006 +                        +                        +                        + SCH O  M               +
2008 +                        +                        +                        +   SC H O M             +
2010 +                        +                        +                        +     SC H O M           +
2012 +                        +                        +                        +        S H O M         + SC
2014 +                        +                        +                        +          SCH O M       +
2016 +                        +                        +                        +            SCH OM      +
2018 +                        +                        +                        +               SH OM    + SC
2020 +                        +                        +                        +                 SHOM   + HC
2022 +                        +                        +                        +                   SHOM + HC
2024 +                        +                        +                        +                      HM+ HS HC HO
2026 +                        +                        +                        +                        + HS HM HC HO

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100      DUPLICATES
```

Figure 34b: Life-function Behavior in Response to Scenario U, Policy P: Health (H), Social-attitudinal (S), Mobility (M), Cognitive-intellectual (C), Communication (O)

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```
                                                SCALES OF PLOT
0.342E 00                0.402E 00                0.462E 00                0.522E 00                0.582E 00   HEALTH           H
0.476E 00                0.498E 00                0.520E 00                0.542E 00                0.564E 00   SOCIAL-ATT       S
0.234E 00                0.318E 00                0.402E 00                0.486E 00                0.569E 00   MOBILITY         M
0.406E 00                0.449E 00                0.491E 00                0.533E 00                0.575E 00   COGNITIVE        C
0.285E 00                0.359E 00                0.433E 00                0.507E 00                0.581E 00   COMMUNICAT       O
0.605E 13                0.605E 13                0.605E 13                0.605E 13                0.605E 13   WORKFORCEP       W
0.101E 08                0.101E 08                0.101E 08                0.101E 08                0.101E 08   COM.INTEGR       I

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 +                   M O H+CS                      +                        +                        +
1942 +                      M O  H CS                  +                        +                        +
1944 +                        +M  O  H CS              +                        +                        +
1946 +                        +    M  O H C S          +                        +                        +
1948 +                        +        M  O H C S      +                        +                        +
1950 +                        +            M  O H C S  +                        +                        +
1952 +                        +                M  O H C+S                       +                        +
1954 +                        +                    M  O+H  CS                   +                        +
1956 +                        +                        M  O  H CS               +                        +
1958 +                        +                        +   M  O  H CS           +                        +
1960 +                        +                        +        M  O H CS       +                        +
1962 +                        +                        +             M O H CS   +                        +
1964 +                        +                        +                  M O HCS                        +
1966 +                        +                        +                       M+OH S                    + SC
1968 +                        +                        +                        +   MO HCS               +
1970 +                        +                        +                        +        MOHCS           +
1972 +                        +                        +                        +             MOHS       + HC
1974 +                        +                        +                        +                   HS   + HM SC HO
1976 +                        +                        +                        +                        H HS HM HC HO
1978 +                        +                        +                        +                   HS   + HM SC HO
1980 +                        +                        +                        +             MOHS       + HC
1982 +                        +                        +                        +        MOHCS           +
1984 +                        +                        +                        +   MO HCS               +
1986 +                        +                        +                       M+OH S                    + SC
1988 +                        +                        +                  M O HCS                        +
1990 +                        +                        +             M O H CS   +                        +
1992 +                        +                        +        M  O H CS       +                        +
1994 +                        +                        +   M  O  H CS           +                        +
1996 +                        +                        M  O  H CS               +                        +
1998 +                        +                    M  O+H C S                   +                        +
2000 +                        +               M   O H C+S                       +                        +
2002 +                        +           M   O H C S  +                        +                        +
2004 +                        +        M  O H C S      +                        +                        +
2006 +                        +    M  O H C S          +                        +                        +
2008 +                        +M  O H C S              +                        +                        +
2010 +                      M O  H CS                  +                        +                        +
2012 +                  M  O H+CS                      +                        +                        +
2014 +               M O H CS +                        +                        +                        +
2016 +            M O HCS     +                        +                        +                        +
2018 +         M OHCS         +                        +                        +                        +
2020 +       MOHCS            +                        +                        +                        +
2022 +    MHCS                +                        +                        +                        + HO
2024 + MHS                    +                        +                        +                        + SC HO
2026 H                        +                        +                        +                        + HS HM HC HO

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 34c: Life-function Behavior in Response to Scenario L, Policy P: Health (H), Social-attitudinal (S), Mobility (M), Cognitive-intellectual (C), Communication (O)

```
                                                SCALES OF PLOT
0.342E 00                0.402E 00                0.462E 00                0.522E 00                0.582E 00   HEALTH           H
0.476E 00                0.498E 00                0.520E 00                0.542E 00                0.554E 00   SOCIAL-ATT       S
0.234E 00                0.318E 00                0.402E 00                0.486E 00                0.569E 00   MOBILITY         M
0.406E 00                0.449E 00                0.491E 00                0.533E 00                0.575E 00   COGNITIVE        C
0.285E 00                0.359E 00                0.433E 00                0.507E 00                0.581E 00   COMMUNICAT       O
0.605E 13                0.605E 13                0.605E 13                0.605E 13                0.605E 13   WORKFORCEP       W
0.101E 08                0.101E 08                0.101E 08                0.101E 08                0.101E 08   COM.INTEGR       I

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 +                   M O H+CS                      +                        +                        +
1942 +                      M O  H CS                  +                        +                        +
1944 +                        +M  O  H CS              +                        +                        +
1946 +                        +    M  O H C S          +                        +                        +
1948 +                        +        M  O H C S      +                        +                        +
1950 +                        +            M  O H C S  +                        +                        +
1952 +                        +                M  O H C+S                       +                        +
1954 +                        +                    M  O+H  CS                   +                        +
1956 +                        +                        M  O  H CS               +                        +
1958 +                        +                        +   M  O  H CS           +                        +
1960 +                        +                        +        M  O H CS       +                        +
1962 +                        +                        +             M O H CS   +                        +
1964 +                        +                        +                  M O HCS                        +
1966 +                        +                        +                       M+OH S                    + SC
1968 +                        +                        +                        +   MO HCS               +
1970 +                        +                        +                        +        MOHCS           +
1972 +                        +                        +                        +             MOHS       + HC
1974 +                        +                        +                        +                   HS   + HM SC HO
1976 +                        +                        +                        +                        H HS HM HC HO
1978 +                        +                        +                        +                   HS   + HM SC HO
1980 +                        +                        +                        +             MOHS       + HC
1982 +                        +                        +                        +        MOHCS           +
1984 +                        +                        +                        +   MO HCS               +
1986 +                        +                        +                       M+OH S                    + SC
1988 +                        +                        +                  M O HCS                        +
1990 +                        +                        +             M O H CS   +                        +
1992 +                        +                        +        M  O H CS       +                        +
1994 +                        +                        +   M  O  H CS           +                        +
1996 +                        +                        M  O  H CS               +                        +
1998 +                        +                    M  O+H C S                   +                        +
2000 +                        +               M   O H C+S                       +                        +
2002 +                        +           M   O H C S  +                        +                        +
2004 +                        +        M  O H C S      +                        +                        +
2006 +                        +    M  O H C S          +                        +                        +
2008 +                        +M  O H C S              +                        +                        +
2010 +                      M O  H CS                  +                        +                        +
2012 +                  M  O H+CS                      +                        +                        +
2014 +               M O H CS +                        +                        +                        +
2016 +            M O HCS     +                        +                        +                        +
2018 +         M OHCS         +                        +                        +                        +
2020 +       MOHCS            +                        +                        +                        +
2022 +    MHCS                +                        +                        +                        + HO
2024 + MHS                    +                        +                        +                        + SC HO
2026 H                        +                        +                        +                        + HS HM HC HO

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

Figure 34d: Life-function Behavior in Response to Scenario ADFS, Policy P: Health (H)M Social-attitudinal (S), Mobility (M), Cognitive-intellectual (C), Communication (O)

was employed as driver. In both Figures 35a and b, curves for environmental change funds, training and counseling funds, and service delivery funds trace exactly the same curve as the curve for physical intervention funds. This fact is communicated by the "duplicates" column on the right.

The same is true for Figures 35c and d. This is because all of these four funding quantities are simple proportions of rehabilitation funding. In Figures 35c and d, the finances for the four technology groups to which the first four funding variables correspond show exponential increases until the year 1974, and this is followed by an exponential decay. In the case of Figure 35d, the decline is to almost "nothing" by the year 2002.

Transfer payments, medical payments, and total costs also vary by scenario, although in every case there is exhibited an exponential rise. The following table indicates the height of these curves by comparison with NNP for the year 2026.

Table 11: Medical & Transfer Payments Compared with NNP in the Year 2026 for each Scenario

Scenario	Transfer Payments	Medical Payments	NNP
M	$8.00\text{x}10^{14}$	$8.05\text{x}10^{13}$	$5.05\text{x}10^{12}$
U	$1.39\text{x}10^{15}$	$1.40\text{x}10^{14}$	$8.90\text{x}10^{12}$
L	$2.70\text{x}10^{14}$	$2.72\text{x}10^{13}$	$2.00\text{x}10^{12}$
A	$1.05\text{x}10^{14}$	$1.05\text{x}10^{13}$	$.50\text{x}10^{12}$

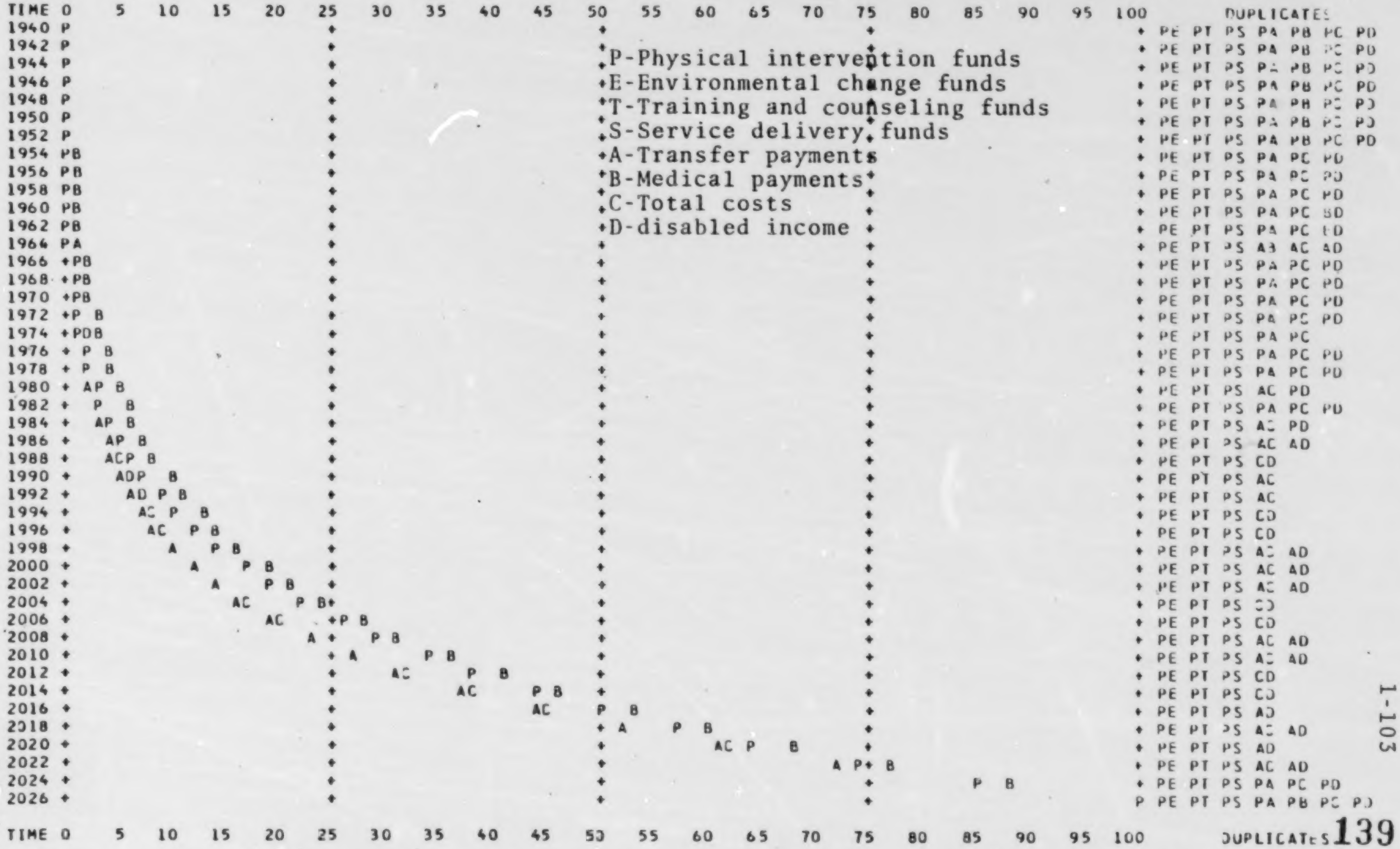
Clearly, using growth rates relative to the base period (1970-1975), transfer payments and medical payments will have far exceeded NNP by the year 2026. This suggests that there must

```
                                                SCALES OF PLOT
0.692E 09                0.351E 12                0.702E 12                0.105E 13                0.140E 13   PI FUNDS          P
0.395E 09                0.201E 12                0.401E 12                0.601E 12                0.802E 12   EC FUNDS          E
0.593E 09                0.301E 12                0.601E 12                0.902E 12                0.120E 13   TC FUNDS          T
0.297E 09                0.151E 12                0.301E 12                0.451E 12                0.601E 12   SD FUNDS          S
0.617E 12                0.348E 15                0.695E 15                0.104E 16                0.139E 16   TRANSFER P        A
0.308E 12                0.352E 14                0.700E 14                0.105E 15                0.140E 15   MEDICAL PA        B
0.925E 12                0.383E 15                0.765E 15                0.115E 16                0.153E 16   TOT  COSTS        C
0.480E 05                0.684E 08                0.137E 09                0.205E 09                0.274E 09   DSABLD INC        D

TIME 0    5    10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95   100      DUPLICATES
1940 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1942 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1944 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1946 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1948 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1950 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1952 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1954 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1956 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1958 PB                       +                        +                        +                        + PE PT PS PA PC PD
1960 PB                       +                        +                        +                        + PE PT PS PA PC PD
1962 AP                       +                        +                        +                        + PE PT PS PB AC AD
1964 AP                       +                        +                        +                        + PE PT PS PB AC AD
1966 AP                       +                        +                        +                        + PE PT PS PB AC AD
1968 AP                       +                        +                        +                        + PE PT PS PB AC AD
1970 DP                       +                        +                        +                        + PE PT PS PA PB PC
1972 DAP                      +                        +                        +                        + PE PT PS PB AC
1974 DAP                      +                        +                        +                        + PE PT PS PB AC
1976 DABP                     +                        +                        +                        + PE PT PS AC
1978 DA BP                    +                        +                        +                        + PE PT PS AC
1980 DA B P                   +                        +                        +                        + PE PT PS AC
1982 D A B P                  +                        +                        +                        + PE PT PS AC
1984 D A B  P                 +                        +                        +                        + PE PT PS AC
1986 D AC B   P               +                        +                        +                        + PE PT PS
1988 D  A  B    P             +                        +                        +                        + PE PT PS AC
1990 +D AC  B    P            +                        +                        +                        + PE PT PS
1992 +D  A   B     P          +                        +                        +                        + PE PT PS AC
1994 +D   A   B       P       +                        +                        +                        + PE PT PS AC
1996 +D    A   B        P     +                        +                        +                        + PE PT PS AC
1998 +D     AC   B         P  +                        +                        +                        + PE PT PS
2000 +D       A    B          +P                       +                        +                        + PE PT PS AC
2002 + D        A    B        +   P                    +                        +                        + PE PT PS AC
2004 +  D         A     B     +       P                +                        +                        + PE PT PS AC
2006 +   D          AC     B  +          P             +                        +                        + PE PT PS
2008 +    D             A     +B              P        +                        +                        + PE PT PS AC
2010 +      D              AC +    B               P   +                        +                        + PE PT PS
2012 +         D              + AC      B              +P                       +                        + PE PT PS
2014 +             D          +       A       B        +       P                +                        + PE PT PS AC
2016 +                   D    +             AC      B  +             P          +                        + PE PT PS
2018 +                        + D                   AC +    B               P   +                        + PE PT PS
2020 +                        +            D           +       AC    B          +  P                     + PE PT PS
2022 +                        +                        + D                A    B+          P             + PE PT PS AC
2024 +                        +                        +                     D  +       A  B      P      + PE PT PS AC
2026 +                        +                        +                        +                        P PE PT PS PA PB PC PD

TIME 0    5    10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95   100      DUPLICATES
```

P-Physical intervention funds
E-Environmental change funds
T-Training and counseling funds
S-Service delivery funds
A-Transfer payments
B-Medical payments
C-Total costs
D-Disabled income

Figure 35a: Funding (Program) Variables Associated with Scenario M, Policy P

```
                                        SCALES OF PLOT
0.692E 09            0.612E 12            J.122E 13            0.183E 13            0.245E 13   PI FUNDS      P
0.395E 09            0.350E 12            0.699E 12            0.105E 13            0.140E 13   EC FUNDS      E
0.593E 09            0.525E 12            0.105E 13            0.157E 13            0.210E 13   TC FUNDS      T
0.297E 09            0.252E 12            0.524E 12            0.786E 12            0.105E 13   SD FUNDS      S
0.617E 12            0.201E 15            0.400E 15            0.600E 15            0.800E 15   TRANSFER P    A
0.308E 12            0.204E 14            0.404E 14            0.505E 14            0.905E 14   MEDICAL PA    B
0.925E 12            0.221E 15            J.441E 15            0.661E 15            0.881E 15   TOT  COSTS    C
0.480E 05            0.588E 07            J.117E 08            0.175E 08            0.234E 08   DSABLD INC    D
```



P-Physical intervention funds
E-Environmental change funds
T-Training and counseling funds
S-Service delivery funds
A-Transfer payments
B-Medical payments
C-Total costs
D-disabled income

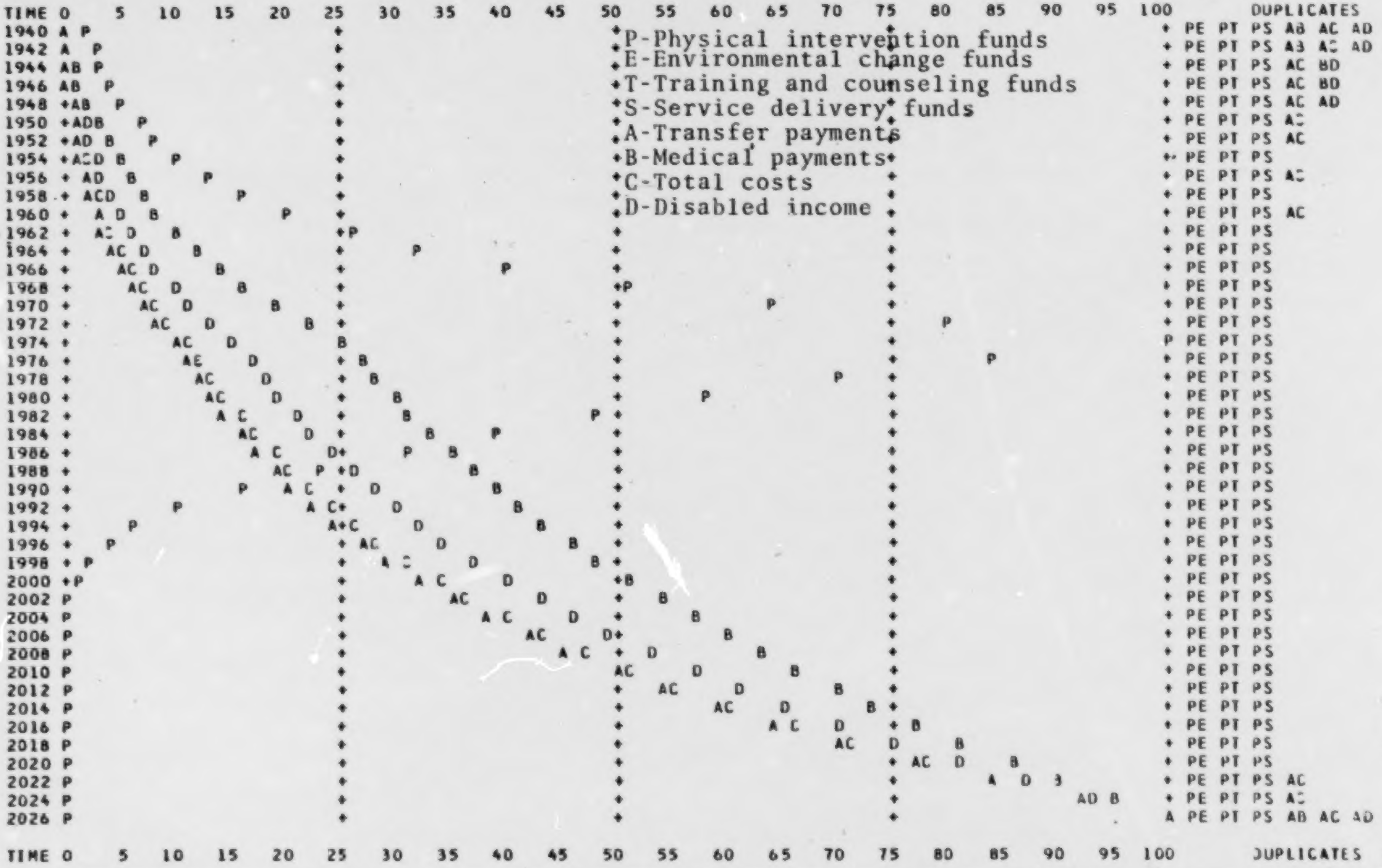
Figure 35b: Funding (Program) Variables Associated with Scenario U, Policy P

Figure 35c: Funding (Program) Variables Associated with Scenario L, Policy P

```
                                                SCALES OF PLOT
0.692E 09                0.869E 10                0.167E 11                0.247E 11                0.327E 11   PI FUNDS          P
0.395E 09                0.496E 10                0.953E 10                0.141E 11                0.187E 11   EC FUNDS          E
0.593E 09                0.745E 10                0.143E 11                0.212E 11                0.280E 11   TC FUNDS          T
0.297E 09                0.372E 10                0.715E 10                0.106E 11                0.140E 11   SD FUNDS          S
0.617E 12                0.681E 14                0.136E 15                0.203E 15                0.270E 15   TRANSFER P        A
0.308E 12                0.703E 13                0.138E 14                0.205E 14                0.272E 14   MEDICAL PA        B
0.925E 12                0.751E 14                0.149E 15                0.223E 15                0.298E 15   TOT  COSTS        C
0.480E 05                0.135E 07                0.265E 07                0.396E 07                0.526E 07   DSABLD INC        D

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
1940 P                        +                        +                        +                        + PE PT PS PA PB PC PD
1942 AP                       +                        +                        +                        + PE PT PS AB AC AD
1944 AP                       +                        +                        +                        + PE PT PS AB AC AD
1946 ABP                      +                        +                        +                        + PE PT PS AC AD
1948 AB P                     +                        +                        +                        + PE PT PS AC BD
1950 AB   P                   +                        +                        +                        + PE PT PS AC BD
1952 AB    P                  +                        +                        +                        + PE PT PS AC BD
1954 +AB     P                +                        +                        +                        + PE PT PS AC AD
1956 +AB        P             +                        +                        +                        + PE PT PS AC BD
1958 +ADB          P          +                        +                        +                        + PE PT PS AC
1960 +ADB               P     +                        +                        +                        + PE PT PS AC
1962 +A DB                   P+                        +                        +                        + PE PT PS AC
1964 + ADB                    +     P                  +                        +                        + PE PT PS AC
1966 + A DB                   +             P          +                        +                        + PE PT PS AC
1968 + AC DB                  +                        P                        +                        + PE PT PS
1970 +  A  DB                 +                        +            P           +                        + PE PT PS AC
1972 +  AC D B                +                        +                        +   P                    + PE PT PS
1974 +   A  D  B              +                        +                        +                        P PE PT PS AC
1976 +   AC  D  B             +                        +                        +              P         + PE PT PS
1978 +    AC  D  B            +                        +                        +     P                  + PE PT PS
1980 +     A   D  B           +                        +                     P  +                        + PE PT PS AC
1982 +     AC   D  B          +                        +             P          +                        + PE PT PS
1984 +      AC   D  B         +                        +      P                 +                        + PE PT PS
1986 +       AC    D  B       +                        +P                       +                        + PE PT PS
1988 +        AC    D  B      +                   P    +                        +                        + PE PT PS
1990 +          A     D  B    +              P         +                        +                        + PE PT PS AC
1992 +           AC     D  B  +         P              +                        +                        + PE PT PS
1994 +             AC     D  B+     P                  +                        +                        + PE PT PS
1996 +              AC      D + P                      +                        +                        + PE PT PS PB
1998 +                 AC    PD   B                    +                        +                        + PE PT PS
2000 +                   AP   +  D   B                 +                        +                        + PE PT PS PC
2002 +                 P    AC+      D   B             +                        +                        + PE PT PS
2004 +              P         +AC      D   B           +                        +                        + PE PT PS
2006 +            P           +   AC      D    B       +                        +                        + PE PT PS
2008 +          P             +       AC      D   B    +                        +                        + PE PT PS
2010 +         P              +           AC      D    B                        +                        + PE PT PS
2012 +       P                +                AC      D   B                    +                        + PE PT PS
2014 +      P                 +                      AC+    D   B               +                        + PE PT PS
2016 +     P                  +                        +   AC     D   B         +                        + PE PT PS
2018 +   P                    +                        +          AC    D  B    +                        + PE PT PS
2020 +   P                    +                        +                  AC   D+ B                      + PE PT PS
2022 +  P                     +                        +                        +  AC  D B               + PE PT PS
2024 + P                      +                        +                        +           AC DB        + PE PT PS
2026 +P                       +                        +                        +                        A PE PT PS AB AC AD

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100       DUPLICATES
```

P-Physical intervention funds
E-Environmental change funds
T-Training and counseling funds
S-Service delivery funds
A-Transfer payments
B-Medical payments
C-Total costs
D-Disabled income

```
                                     SCALES OF PLOT
0.264E 02        0.817E 10        0.163E 11        0.245E 11        0.327E 11   PI FUNDS     P
0.151E 02        0.467E 10        0.934E 10        0.140E 11        0.187E 11   EC FUNDS     E
0.226E 02        0.700E 10        0.140E 11        0.210E 11        0.280E 11   TC FUNDS     T
0.113E 02        0.350E 10        0.700E 10        0.105E 11        0.140E 11   SD FUNDS     S
0.617E 12        0.266E 14        0.526E 14        0.786E 14        0.105E 15   TRANSFER P   A
0.308E 12        0.286E 13        0.541E 13        0.796E 13        0.105E 14   MEDICAL PA   B
0.925E 12        0.295E 14        0.580E 14        0.865E 14        0.115E 15   TOT  COSTS   C
0.480E 05        0.675E 06        0.133E 07        0.193E 07        0.255E 07   DSABLD INC   D
```



P-Physical intervention funds
E-Environmental change funds
T-Training and counseling funds
S-Service delivery funds
A-Transfer payments
B-Medical payments
C-Total costs
D-Disabled income

Figure 35c: Funding (Program) Variables Associated with Scenario L, Policy P

be a considerable slowing of these rates of growth in the near future. These concepts are corroborated by the work at Rutgers [10] in which it was observed that transfer payments would exceed NNP in the 1990's.

The fact that medical payments, transfer payments, disabled income, and total costs do not decline for scenarios L and A indicates a certain lack of robustness in this sector of the model.

Results from the Consequence Sector. Consequence sector results are plotted in Figure 36 (a, b, c, and d). In its present form, the model exhibits exponential growth in adapted environment, disabled employment, facilities for disabled, rehabilitation rate, disabled status, and advocacy position for scenarios M and U as indicated in Figures 36a and b respectively. The growth is more pronounced under the upper scenario as depicted in Figure 36b.

By contrast curves for perceived environment, public reaction (attitude) and facilities for abled all exhibit some decline for scenarios M and U respectively.

In Figures 36c and d, the growth is much more abated and almost reaches a stand-still in some of the "growth" variables, notably adapted environment. Also in Figures 36c and d, disabled status rises to a peak in the year 1978 and declines rapidly thereafter.

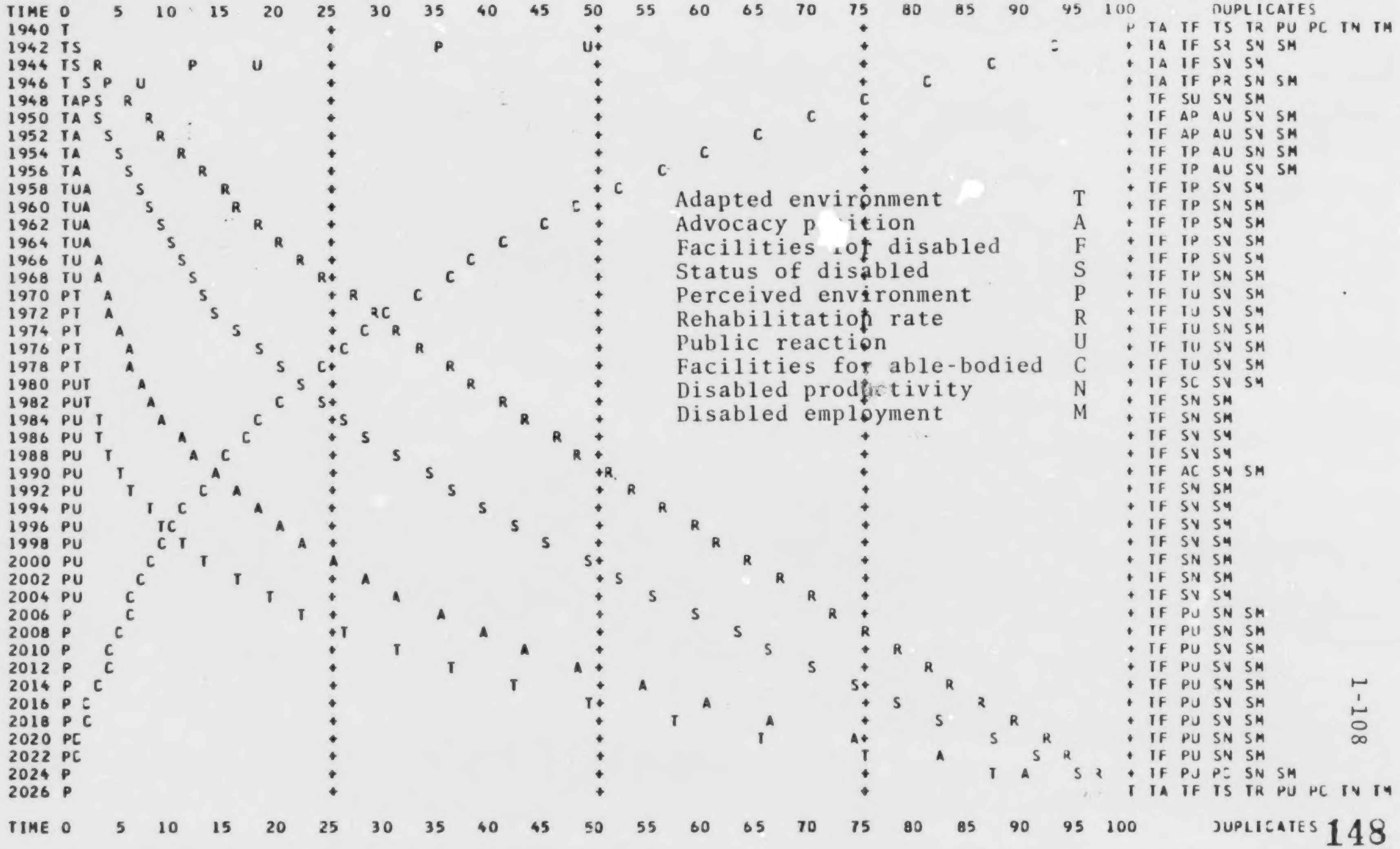
```
                                                SCALES OF PLOT
0.0                      0.353E 11                0.726E 11                0.109E 12                0.145E 12   ADAPTED EN      T
0.651E 04                0.201E 06                0.395E 06                0.590E 06                0.784E 06   ADVOCACY P      A
0.198E 08                0.361E 10                0.720E 10                0.108E 11                0.144E 11   FAC DISABL      F
0.996E-02                0.304E-01                0.509E-01                0.713E-01                0.918E-01   STATUS DIS      S
0.258E-02                0.152E 00                0.331E 00                0.451E 00                0.600E 00   PERC ENVRN      P
0.500E 05                0.268E 08                0.536E 08                0.803E 08                0.107E 09   REHAB RATE      R
0.258E-02                0.968E-01                0.191E 00                0.285E 00                0.379E 00   PUBLIC REA      U
0.845E 11                0.313E 12                0.542E 12                0.771E 12                0.100E 13   FAC F ABLD      C
0.199E-01                0.608E-01                0.132E 00                0.143E 00                0.184E 00   DSABLD PRD      N
0.607E 01                0.186E 02                0.310E 02                0.435E 02                0.550E 02   DSABLD EMP      M

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100      DUPLICATES
1940 T                        +                        +                        +                        P TA TF TS TR PU PC TN TM
1942 A T                                 P             U                        +                 C      + AF AS TR AN AM
1944 AST R         P      U   +                        +                        +           C            + AF SN SM
1946 AST   P  U               +                        +                        +     C                  + AF PR SN SM
1948 A TP U  R                +                        +                        C                        + AF TS TN TM
1950 FAT U     R              +                        +                   C    +                        + TS TP TN TM
1952 FATS        R            +                        +              C         +                        + TP SU SN SM
1954 FATUS         R          +                        +         C              +                        + TP SN SM
1956 FAPTS           R        +                        +     C                  +                        + TU SN SM
1958 FAPT S             R     +                        + C                      +                        + TU SN SM
1960 FAPT  S              R   +                      C +                        +                        + TU SN SM
1962 F AT  S                R +                   C    +                        +                        + AP TU SN SM
1964 F AT   S                 +R              C        +                        +                        + AP TU SN SM
1966 F AT    S                +  R         C           +                        +                        + AP TU SN SM
1968 +FAT     S               +     R    C             +                        +                        + AP TU SN SM
1970 +FPT      S              +       CR               +                        +                        + TA TU SN SM
1972 +FPT       S             +    C      R            +                        +                        + TA TU SN SM
1974 +FPTA       S            +  C           R         +                        +                        + TU SN SM
1976 +FPUT        S           +C                R      +                        +                        + TA SN SM
1978 + FUTA        S         C+                    R   +                        +                        + FP SN SM
1980 + FU TA         S     C  +                       R+                        +                        + FP SN SM
1982 + PF TA           S C    +                        + R                      +                        + FU SN SM
1984 + PUF TA          C S    +                        +    R                   +                        + SN SM
1986 + PUF  TA        C    S  +                        +       R                +                        + SN SM
1988 + PU  F T A    C        S+                        +          R             +                        + SN SM
1990 + PU   F T A  C          +S                       +             R          +                        + SN SM
1992 + PU    = T AC           +   S                    +                 R      +                        + SN SM
1994 + PU      FCT A          +      S                 +                    R   +                        + SN SM
1996 + PU      C F T A        +        S               +                       R+                        + SN SM
1998 + PU     C    F T A      +           S            +                        + R                      + SN SM
2000 + PU    C        F T A   +               S        +                        +     R                  + SN SM
2002 + PU   C            F T A+                  S     +                        +        R               + SN SM
2004 + PU  C                F T A                   S  +                        +          R             + SN SM
2006 +PU   C                  + F TA                   +S                       +             R          + SN SM
2008 +PU  C                   +      FTA               +    S                   +               R        + SN SM
2010 +P  C                    +          F TA          +        S               +                R       + PU SN SM
2012 +P  C                    +                FTA     +            S           +                  R     + PU SN SM
2014 +P C                     +                      FT+                S       +                   R    + TA PU SN SM
2016 PUC                      +                        +    T                S  +                    R   + TA TF SN SM
2018 PUC                      +                        +           AT           +S                    R  + AF SN SM
2020 PC                       +                        +                  AFT   +     S                R + PU SN SM
2022 PC                       +                        +                        +  AFT      S           R+ PU SN SM
2024 P                        +                        +                        +             AT  S     R+ AF PU PC SN SM
2026 P                        +                        +                        +                        T TA TF TS TR PU PC TN TM

TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100      DUPLICATES
```

Adapted environment T
Advocacy position A
Facilities for disabled F
Status of disabled S
Perceived environment P
Rehabilitation rate R
Public reaction U
Facilities for able-bodied C
Disabled productivity N
Disabled employment M

Figure 36a: Consequence Sector Behavior in Response to Scenario M, Policy P

Figure 36b: Consequence Sector Behavior in Response to Scenario U, Policy P

```
                                                   SCALES OF PLOT
0.0                      0.471E 11                 0.943E 11                 0.141E 12                 0.189E 12   ADAPTED EN    T
0.498E 03                0.119E 05                 0.233E 05                 0.346E 05                 0.460E 05   ADVOCACY P    A
0.198E 08                0.482E 10                 0.962E 10                 0.144E 11                 0.192E 11   FAC DISABL    F
0.996E-02                0.251E-01                 0.402E-01                 0.553E-01                 0.704E-01   STATUS DIS    S
0.124E-01                0.159E 00                 0.306E 00                 0.453E 00                 0.600E 00   PERC ENVRN    P
0.500E 05                0.341E 08                 0.682E 08                 0.102E 09                 0.136E 09   REHAB RATE    R
0.123E-01                0.104E 00                 0.196E 00                 0.288E 00                 0.379E 00   PUBLIC REA    U
0.845E 11                0.313E 12                 0.542E 12                 0.771E 12                 0.100E 13   FAC F ABLD    C
0.199E-01                0.501E-01                 0.804E-01                 0.111E 00                 0.141E 00   DSABLD PRD    N
0.607E 01                0.153E 02                 0.245E 02                 0.337E 02                 0.429E 02   DSABLD EMP    M
```

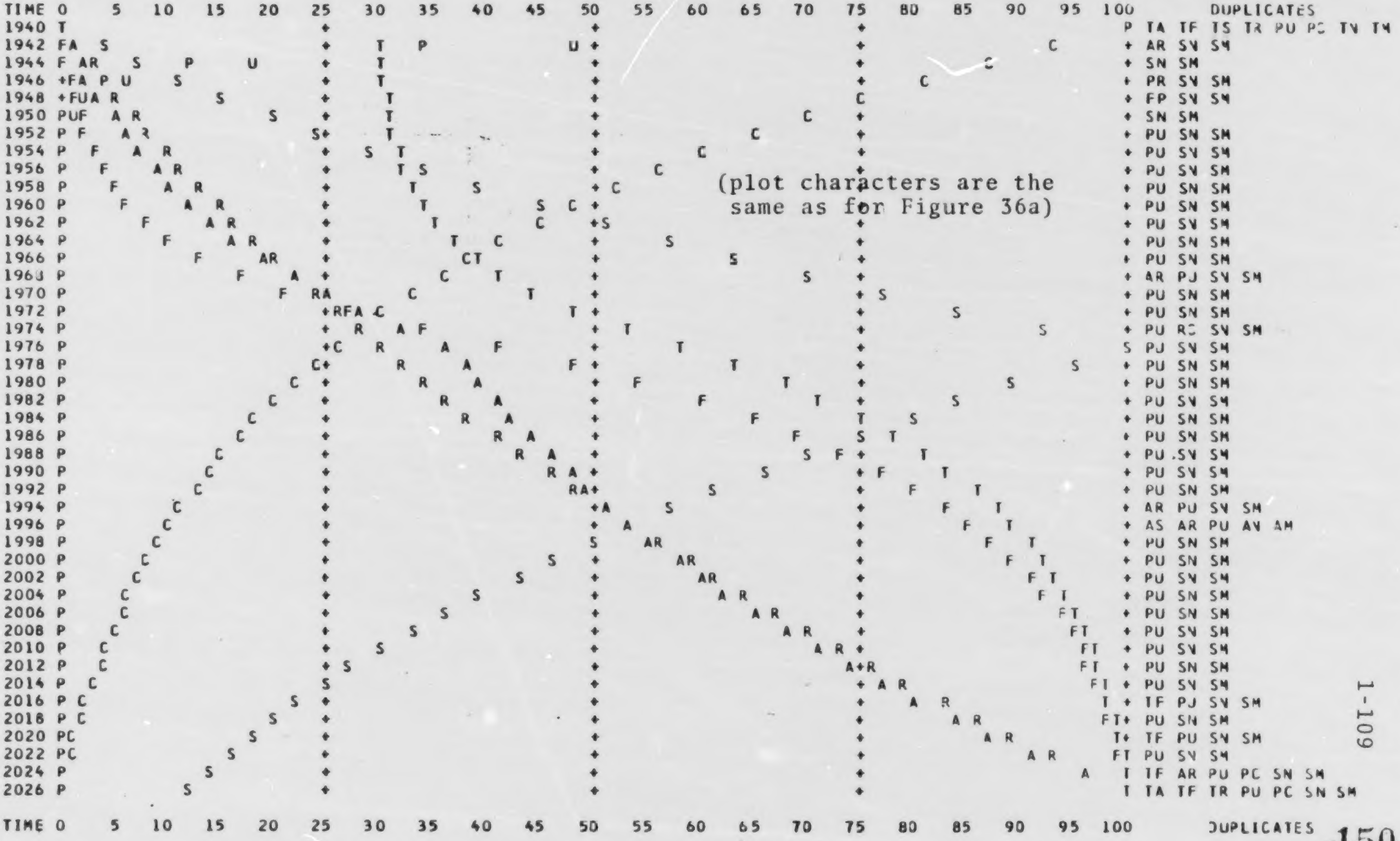


```
TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100      DUPLICATES
1940 T                        +                        +                        +                        P TA TF TS TR PU PC TN TM
1942 TS                       +         P             U+                        +                  C     + TA TF SR SN SM
1944 TS R        P     U      +                        +                        +            C           + TA TF SV SM
1946 T S P  U                 +                        +                        +      C                 + TA TF PR SN SM
1948 TAPS  R                  +                        +                        C                        + TF SU SN SM
1950 TA S    R                +                        +                    C   +                        + TF AP AU SV SM
1952 TA  S    R               +                        +               C        +                        + TF AP AU SV SM
1954 TA   S     R             +                        +          C             +                        + TF TP AU SN SM
1956 TA    S      R           +                        +      C                 +                        + TF TP AU SV SM
1958 TUA    S       R         +                        + C                      +                        + TF TP SV SM
1960 TUA     S       R        +                      C +                        +                        + TF TP SN SM
1962 TUA      S        R      +                   C    +                        +                        + TF TP SN SM
1964 TUA       S         R    +               C        +                        +                        + TF TP SV SM
1966 TU A       S          R  +            C           +                        +                        + TF TP SV SM
1968 TU A        S           R+          C             +                        +                        + TF TP SN SM
1970 PT  A        S           + R     C                +                        +                        + TF TU SV SM
1972 PT  A         S          +   RC                   +                        +                        + TF TU SV SM
1974 PT   A          S        +  C  R                  +                        +                        + TF TU SN SM
1976 PT    A           S      +C       R               +                        +                        + TF TU SV SM
1978 PT    A             S   C+          R             +                        +                        + TF TU SV SM
1980 PUT    A              S  +            R           +                        +                        + TF SC SV SM
1982 PUT     A           C   S+               R        +                        +                        + TF SN SM
1984 PU T     A         C     +S                R      +                        +                        + TF SN SM
1986 PU T       A      C      +  S                  R  +                        +                        + TF SV SM
1988 PU  T       A  C         +     S                 R+                        +                        + TF SV SM
1990 PU   T        A          +        S               +R                       +                        + TF AC SN SM
1992 PU    T      C  A        +          S             +   R                    +                        + TF SN SM
1994 PU      T  C      A      +             S          +      R                 +                        + TF SV SM
1996 PU       TC         A    +                S       +         R              +                        + TF SV SM
1998 PU       C T          A  +                   S    +           R            +                        + TF SV SM
2000 PU      C    T           A                       S+              R         +                        + TF SN SM
2002 PU     C        T        +  A                     + S               R      +                        + TF SN SM
2004 PU    C            T     +     A                  +    S               R   +                        + TF SV SM
2006 P     C               T  +         A              +         S            R +                        + TF PU SN SM
2008 P    C                   +T             A         +             S          R                        + TF PU SN SM
2010 P   C                    +     T           A      +                S       +   R                    + TF PU SV SM
2012 P   C                    +          T            A+                    S   +      R                 + TF PU SV SM
2014 P  C                     +                T       +    A                  S+        R               + TF PU SN SM
2016 P C                      +                       T+          A             +   S       R            + TF PU SN SM
2018 P C                      +                        +       T        A       +       S      R         + TF PU SV SM
2020 PC                       +                        +               T       A+            S    R      + TF PU SN SM
2022 PC                       +                        +                        T       A        S  R    + TF PU SN SM
2024 P                        +                        +                        +            T  A    S R + TF PU PC SN SM
2026 P                        +                        +                        +                        T TA TF TS TR PU PC TN TM
TIME 0    5   10   15   20   25   30   35   40   45   50   55   60   65   70   75   80   85   90   95  100      DUPLICATES
```

Adapted environment T
Advocacy position A
Facilities for disabled F
Status of disabled S
Perceived environment P
Rehabilitation rate R
Public reaction U
Facilities for able-bodied C
Disabled productivity N
Disabled employment M

Figure 36c: Consequence Sector Behavior in Response to Scenario L, Policy P

```
                                                   SCALES OF PLOT
0.0                     0.168E 10               0.335E 10               0.503E 10               0.670E 10   ADAPTED EN    T
0.851E 05               0.375E 06               0.665E 06               0.956E 06               0.125E 07   ADVOCACY P    A
0.198E 08               0.137E 09               0.255E 09               0.372E 09               0.490E 09   FAC DISABL    F
0.996E-02               0.125E-01               0.151E-01               0.177E-01               0.203E-01   STATUS DIS    S
0.146E-01               0.161E 00               0.307E 00               0.454E 00               0.600E 00   PERC ENVRN    P
0.500E 05               0.386E 08               0.771E 08               0.116E 09               0.154E 09   REHAB RATE    R
0.145E-01               0.106E 00               0.197E 00               0.288E 00               0.379E 00   PUBLIC REA    U
0.845E 11               0.313E 12               0.542E 12               0.771E 12               0.100E 13   FAC F ABLD    C
0.199E-01               0.251E-01               0.302E-01               0.354E-01               0.405E-01   DSABLD PRD    N
0.607E 01               0.765E 01               0.922E 01               0.108E 02               0.124E 02   DSABLD EMP    M
```



(plot characters are the same as for Figure 36a)

```
                                    SCALES OF PLOT
0.0              0.815E 09        0.163E 10        0.245E 10        0.326E 10   ADAPTED EN   T
0.111E 07        0.478E 07        0.845E 07        0.121E 08        0.158E 08   ADVOCACY P   A
0.198E 08        0.101E 09        0.183E 09        0.264E 09        0.346E 09   FAC DISABL   F
0.996E-02        0.125E-01        0.151E-01        0.177E-01        0.202E-01   STATUS DIS   S
0.146E-01        0.161E 00        0.307E 00        0.454E 00        0.600E 00   PERC ENVRN   P
0.500E 05        0.353E 08        0.706E 08        0.106E 09        0.141E 09   REHAB RATE   R
0.145E-01        0.106E 00        0.197E 00        0.288E 00        0.379E 00   PUBLIC REA   U
0.845E 11        0.313E 12        0.542E 12        0.771E 12        0.100E 13   FAC F ABLD   C
0.199E-01        0.251E-01        0.302E-01        0.353E-01        0.405E-01   DSABLD PRD   V
0.607E 01        0.764E 01        0.921E 01        0.108E 02        0.123E 02   DSABLD EMP   M
```

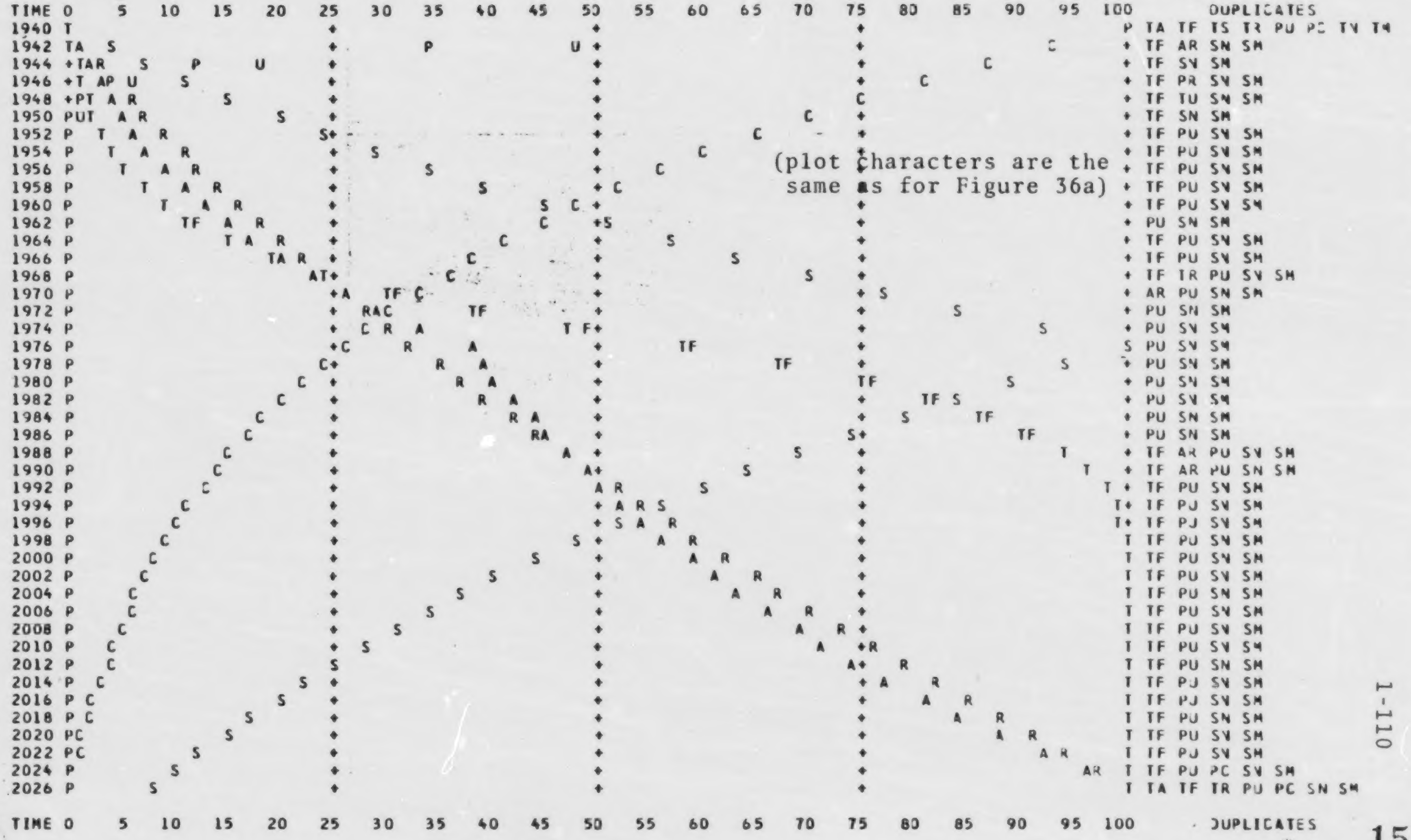


Figure 36d: Consequence Sector Behavior in Response to Scenario ADFS, Policy P

Conclusion

The summarizing statements which embody this conclusion are of three categories. First the relative utility of the various modeling methodologies tried is assessed. Secondly, the absence of data which the formal modeling activity has tended to make more apparent is discussed, and finally comments about the original objectives of this study and how and to what extent they were achieved are provided.

The study has used in various contexts the following methodologies -- causal modeling [12], interpretive structural modeling [14-17], Kane-style modeling [4, 6, 18, 19, 20], and Forrester-style modeling [2, 3, 7, 13]. The reader is referred to Appendices A and B for comparative discussions of these methodologies in contexts other than utility.

From an overall utility standpoint the methodologies are ranked as shown:

causal modeling
Kane-style modeling
Forrester-style modeling
interpretive structural modeling.

However, the specific context in which these various methodologies were tried bears strongly upon the ranking depicted above. From a modeling perspective, the overall study has been very time and budget constrained. Less than 5% of the total funds were allocated to this addendum activity. As a consequence there was neither time nor budget to perform time-consuming participatory exercises, such as interpretive structural modeling. This methodology, when tried among members of the Technology Assessment team, was found to provoke much time-consuming discussion.

The causal modeling, as previously discussed, was on the other hand, found to be most useful in the work-sessions because of the expediency with which it resulted in a pictorial structure of the probable interactions which characterize the issue at hand. It served to summarize the important consequence statements that were made during the sessions and facilitated the formulation of the GSIM (or Kane-style) models.

The Kane-style models served to generate the behavioral implications associated with a particular program thrust. Thus the GSIM models further stimulated the development of consequences, especially when those consequences were behavioral (as opposed to structural) in substance.

Finally, our work with a formal Forrester model has suggested that a precision replication of the rehabilitation subsystem will require precise data about demographics, technologies, and consequences. Any formal Forrester model which is formulated conventionally is somewhat less efficient than GSIM models for generating behavioral consequences. However, the Forrester approach has the advantages of authenticity, accuracy, rigor, and validity. The Forrester approach is much more time-consuming than GSIM and currently runs in batch mode when executed on the computer. GSIM by contrast, is quick, inexpensive, and runs in time-sharing mode thereby allowing for quicker turn-around and policymaker participation.

Having discussed the various methodologies considered and their relative utilities, the insights developed while formulating a Forrester-style model are elaborated upon next. For some, these platitudes will be dismissed as inappropriately mordant. For others, and hopefully, there will be many, the insights shared herein will serve to enlighten and stimulate. Modelers, perceive their role in society as one of agitation and provocation toward new and improved strategies for problem-solving (and they take that role seriously). Inane discussions have no impact; therefore what follows is deliberately acrimonious.

The rehabilitation system is a fragmented collection of programs, technologies, and institutions for solving the problems of disabled persons in the United States. In a metaphorical sense, it resembles a growing, stumbling adolescent. Its mechanisms for feedback are crude and imprecise. Its mechanism for control is uncoordinated and clumsy. There is no standardized process for evaluating how well it does its job and there is no formal procedure for internal rearrangement and reallocation for increased efficacy and efficiency. This being knows only vaguely where it is going, but as to how well it is doing, how long it will take to get there, and at what cost, it knows almost nothing. Its goals, therefore, appear only vaguely formulated.

In order for this being to know how well it is doing, it must measure its processes, its programs, its technologies. Such measurements require precisionally specific definitions for such vaguely defined concepts as rehabilitation, life-functions, disability, etc. Since the formal modeling activity was unable to surface precise, measurable, quantifiable definitions for these terms, it is recommended that standardized, quantifiable definitions be established for

1) each life-function in relation to "normalcy",
2) rehabilitation,
3) each demographic disability group,

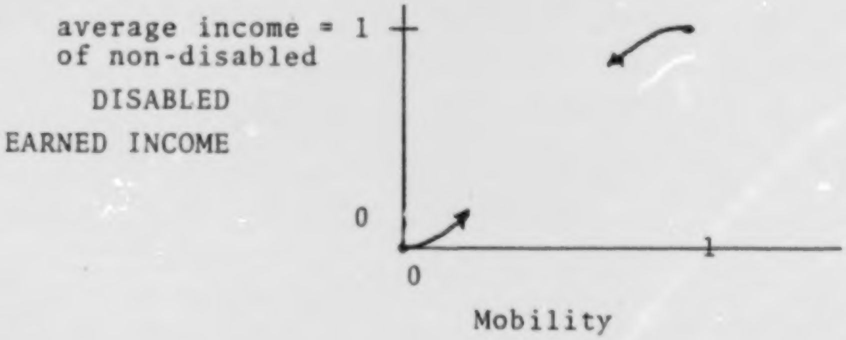
and that these definitions be used to collect (or measure) data on

1) the number of persons within each disability group, broken down by age and sex,
2) the relative improvement each technology produces within each life-function for a particular disability type,
3) the number of persons rehabilitated per year,
4) costs on a per annum per capita basis to apply a particular technology.

Items numbered (2) and (4) above stem from the realization that there appears not to be any data available specifying the degree of efficacy which a particular program thrust or technology induces or at what cost. It is conceptually possible to measure an individual's life-function levels (once these are quantified) both before and after the technology is applied. Theoretically therefore, it would be possible to assess the relative efficacy (in terms of life-function improvement) associated with a particular technology. (Then technologies which are substitutionary could be more objectively compared.) Strategies consisting of whole groups of technologies could be contrasted with regard to efficacy and costs.

In addition, little or no hard data was available for describing precisely how the various life-function levels affected such consequence variables as disabled employment, disabled status, disabled income, disabled productivity. The worksessions produced some GSIM coefficients which provide a subjective indication as to the strength of the interaction between say health and disabled income. This is hardly an adequate substitute for correlative statistical or regression parameters which interrelate the various endogenous variables.

Members of the local technology assessment team were asked to show by means of a simple curve how a life-function, such as mobility might affect disabled income, in which mobility was quantified to the range zero to one. An example follows.



It was argued that the points (0,0) and (1,1) would be on the curve because without at least some mobility (in his hands, his fingers, etc.) there would be no possibility for earning an income, and it was suggested that if the mobility were normal or

"1", then the possibility for earning at least an average income would also be 1 insofar as the mobility issue is concerned. Team members were unable to assert with any confidence what the shape of that or any closely related curves should be. This observation reflects, once again, the acute absence of hard data, in this case objective data about how life-function levels affect consequence variables.

We have been discussing the lack of data necessary to specify two operators. Specifically, the mapping M_1 from technologies T and disabilities D to life-functions L is unknown as is the mapping M_2 from life-function L into consequence variables C. Thus the transformations

$$M_1: \; T \times D \longrightarrow L$$
$$M_2: \; L \longrightarrow C$$

had to be contrived in the model to illustrate how it would work had the data been available.

What can be done to sharpen overall comprehension and to improve behavior of the rehabilitation subsystem? As suggested in Chapter 7, Volume 1. precise, standardized definitions together with a centralized committee for monitoring, collecting data, coordinating and controlling the process are greatly needed. Until the imprecision is removed, the art of rehabilitation will remain just that, an art. Improvements in the efficiency of rehabilitation strategies will not be perceived except in cases where significant breakthroughs occur in the technology and extremization of such efficiency will be impossible. Evidently, the current technology for measuring, monitoring, evaluating, integrating, coordinating and controlling rehabilitation programs must be assessed as primitive.

This brings the discussion back to the formal Forrester-style model. How well does it replicate the structure and dynamics of the rehabilitation subsystem? The structure is there, but the dynamics for the demographic, life functions, and consequence sectors are conjecture only. The dynamics will remain so until hard data is available. Efforts to acquire the data have led to the conclusion that such information is unavailable anywhere in the literature and would have to be empirically collected over a period of perhaps years. The data requirements for the model would easily run into the millions of dolars.

The following summarizes the main contributions of this study.

1. Life-function indices tend to accumulate the affects of rehabilitation funding (especially for disabled populations with zero entrance (disabling) rates) (See Appendix II).
2. Consequence variables (including rehabilitation rate, disabled productivity, employment, income, and status) are proportional functions of the life-function indices (See Appendix II).
3. More than enough funds are available in scenarios M and U for maintenance and expansion of rehabilitation programs, but maintenance is not possible in scenarios L and A (See Table 9).
4. Under scenarios M and U, one can expect the disabled populations to age or grow older, with those remaining being more severely impaired (See Figure 30).
5. In the absence of precise definitions and hard data, detailed assessment of the performance and efficiency of the rehabilitation subsystem is impossible.

6. This study has yielded pertient insight regarding the relative utility of various methodologies employed within the context of technology assessment.

7. This study has produced a myriad of computer-generated consequence data for various program thrusts within each of the technology groups, together with structural delineations describing how each technology group interacts. (See Chapter 6, Vol. I, and Vol. V.)

8. Finally, this study has contributed both to the methodology of technology assessment (See Project Paper No. 8, Vol. II) and to the understanding of how causality is characterized by various modeling methodologies employed in technology assessment.

Appendix I

On the Relationship Between KSIM and GSIM

A. The KSIM Algorithm

To employ the KSIM Algorithm one identifies a set of variables $\{x_i\}$ whose dynamic interactions one wishes to model. Each variable must be normalized over the range 0 to 1. One proceeds by formulating a Cross-Impact matrix as shown in Figure 1.

$$\begin{array}{c|ccccc}
 & x_1 & x_2 & x_3 & x_4 & x_5 \\
\hline
x_1 & \alpha_1 & \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} \\
\hline
x_2 & \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} & \alpha_{25} \\
\hline
x_3 & \alpha_{31} & \alpha_{32} & \alpha_{33} & \alpha_{34} & \alpha_{35} \\
\hline
x_4 & \alpha_{41} & \alpha_{42} & \alpha_{43} & \alpha_{44} & \alpha_{45} \\
\hline
x_5 & \alpha_{51} & \alpha_{52} & \alpha_{53} & \alpha_{54} & \alpha_{55} \\
\hline
\end{array}$$

Figure 1: The Cross Impact (α) Matrix

A Cross-Impact Matrix entry α_{ij} in column corresponding to x_j and row corresponding to x_i will be negative, zero, or positive depending upon whether variable x_i accumulates a decreasing impact from x_j, no impact from x_j, or else accumulates an increasing impact from x_j, respectively. The implication is that variable x_i accumulates an impact $\alpha_{ij}x_j$ even though x_j does not change provided the entry α_{ij} is non-zero. The rate of change of x_i depends upon the net impact of all impacting quantities $\alpha_{ij}x_j$.

Similarly, a proportional impact matrix is formulated as shown in Figure 2.

$$\begin{array}{c|ccccc}
 & x_1 & x_2 & x_3 & x_4 & x_5 \\
\hline
x_1 & \beta_{11} & \beta_{12} & \beta_{13} & \beta_{14} & \beta_{15} \\
\hline
x_2 & \beta_{21} & \beta_{22} & \beta_{23} & \beta_{24} & \beta_{25} \\
\hline
x_3 & \beta_{31} & \beta_{32} & \beta_{33} & \beta_{34} & \beta_{35} \\
\hline
x_4 & \beta_{41} & \beta_{42} & \beta_{43} & \beta_{44} & \beta_{45} \\
\hline
x_5 & \beta_{51} & \beta_{52} & \beta_{53} & \beta_{54} & \beta_{55} \\
\hline
\end{array}$$

Figure 2: The Proportional-Impact (β) Matrix

An entry β_{ij} is negative, zero, or positive depending upon whether an increase in variable x_j results in a decrease in x_i, no change in x_i, or an increase in variable x_i respectively. The implication is that variable x_i does not change unless the quantity $\beta_{ij}x_j$ changes. The change in x_i is the net change in the quantities $\beta_{ij}x_j$. A negative entry implies the existence of a negative proportional relation while a positive entry implies the existence of a positive proportional relation.

The algorithm is implemented by iteration of a numerical solution to the following form of differential equation involving the entries in both the Cross-Impact (α) and Proportional-Impact (β) matrices

$$\frac{dx_i}{dt} = \sum_{j=1}^{N} \left(\alpha_{ij}x_j + \beta_{ij}\frac{dx_i}{dt}\right)(-x_i \ln x_i) \qquad (1)$$

where $i = 1,\ldots.,N$

and N is the number of variables.

A numerical solution of this equation takes the form of successive iteration of the following algorithm used by the KSIM language.

Step 1. Compute $P_i(T)$ for i=1 to N where

$$P_i(T) = \frac{1 + 1/2\ DT \sum_{j=1}^{N} \left[\left| \alpha_{ij} + \frac{\beta_{ij}}{x_j} \frac{dx_j}{dt} \right| - (\alpha_{ij} + \frac{\beta_{ij}}{x_j} \frac{dx_i}{dt}) \right] x_j}{1 + 1/2\ DT \sum_{j=1}^{N} \left[\left| \alpha_{ij} + \frac{\beta_{ij}}{x_j} \frac{dx_j}{dt} \right| + (\alpha_{ij} + \frac{\beta_{ij}}{x_j} \frac{dx_i}{dt}) \right] x_j} \quad (2)$$

More simply, $P_i(T)$ is an exponent computed at each iteration for each variable x_i such that

$$P_i(T) = \frac{1 + DT\ |\text{Sum of negative impacts on } x_i|}{1 + DT\ |\text{Sum of positive impacts on } x_i|} \quad (3)$$

and DT is the time step increment per iteration.

Step 2. Given the current value of $x_i(T)$ compute the value of x_i at T + DT using $P_i(T)$ and the relation

$$x_i(T + DT) = x_i(T)^{P_i(T)} \quad (4)$$

Step 3. If the number of iterations is less than the specified number then repeat Step 1 and Step 2 using the current values of x_i, otherwise stop iterating.

From equation (1) we see that an estimate of $\frac{dx_i}{dt}$ involves the impacts $\alpha_{ij}x_j$, $\beta_{ij} \frac{dx_j}{dt}$, and the modulating function $(-x_i\ \ell n\ x_i)$. The term $(-x_i\ \ell n\ x_i)$ is a function whose value is zero for $x_i = 1$ and $x_i = 0$ and positive for $0 < x < 1$. The multiplicative term $(-x_i\ \ell n\ x_i)$ forces the rate of change of x_i

to be 0 at $x_i = 0$ and $x_i = 1$.

We see that the KSIM algorithm is the repetitive iteration of the above steps to portray the dynamics of pair-wise interactions. The basic requirements that must be met to utilize the algorithm are the following:

1. A set of variables must be specified.
2. All variables must be normalized in the range zero to one.
3. All variables must be given an initial value in the range zero to one.
4. Two interaction matrices must be specified.
    - (a) the Cross-Impact (α) matrix
    - (b) the proportional (β) impact matrix.

Additionally it is observed changes in variables will approach zero rate of change as their values approach zero or one. The function ($-x_i \ln x_i$) which appears explicitly in the differential equation and implicitly in the numerical solution that attenuates the net change is shown in Figure 3.

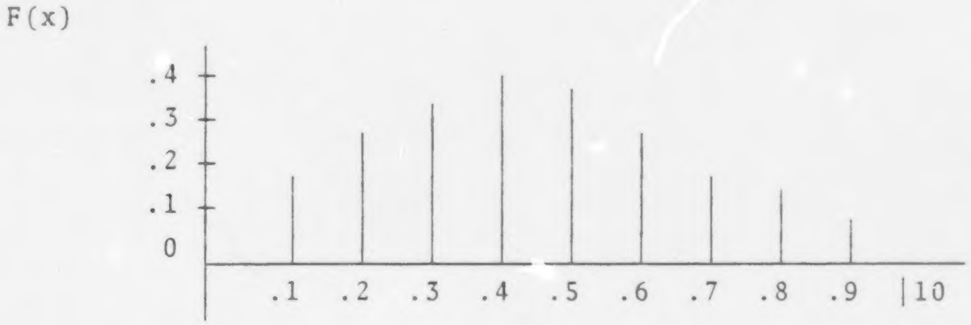
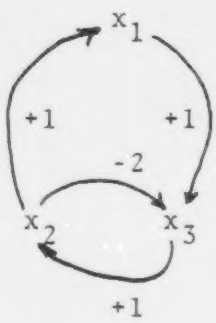


Figure 3: The Function $F(x) = -x_i \ln x_i$

B. Causal Relations and the Use of the KSIM Algorithm

The user is faced with the problem of specifying a set of variables $\{x_i\}$, a set of interactions α and β and a set of initial conditions for each of the variables. The set of variables $\{x_i\}$ is usually obtained by observation, by interrogation, or by brainstorming. The initial conditions are obtained by estimating the normalized initial values. The specification of α and β is more difficult, but often is aided by the use of causal diagrams as shown in Figure 4.



causal diagram

$$\begin{array}{c|ccc|}
 & x_1 & x_2 & x_3 \\
x_1 & 0 & +1 & 0 \\
x_2 & 0 & 0 & +1 \\
x_3 & +1 & -2 & 0
\end{array}$$

interaction matrix

Figure 4: Causal Diagram and Equivalent Interaction Matrix

For each causal diagram there exists an equivalent interaction matrix as shown in Figure 4. An entry in the interaction matrix records the sign, magnitude, and direction of a causal linkage depicted in the causal diagram. The causal diagrams and interaction matrices serve as powerful aids to a group modeling effort. The causal diagram helps to avoid errors of commission while a consideration of pair-wise interaction helps to avoid errors of ommission.

Given a causal diagram, it is then necessary to determine the class and magnitude of the causal linkage. A causal relation may belong to either the accumulative class (α) or the proportional class (β) or conceivably both.

Accumulative causality is represented in the monovariate case by the following differential equation:

$$\frac{dx_i}{dt} = \alpha_{ij}x_j, \; x_i(T_o) = \chi_o \tag{5}$$

a solution has the form

$$x_i(T) = \chi_o + \int_{T_o}^{t} \alpha_{ij} \, x_j(\tau) \, d\tau.$$

The solution illustrates the fact that x_i accumulates the impact $\alpha_{ij}x_j$ over the interval T_o to t. Examples of this type of relationship include petroleum reserves to petroleum consumption, savings to compound interest, population to births and deaths, etc.

Proportion causality is represented in the monovariate case by the following differential equation:

$$\frac{dx_i}{dt} = \beta_{ij} \frac{dx_j}{dt} \tag{6}$$

When integrated one obtains a solution in the form of a proportionality given as follows:

$$x_i(T) = \beta_{ij}x_j(T) + \eta \tag{7}$$

where η is a constant of integration. Thus the β matrix is used to represent proportional behavior. Examples of proportional behavior include deposits to savings, voltage to current, inventory to shipments, etc.

The appropriate class for a causal relation is found by answering the following questions:

1. Does a change in x_i occur only when a change in x_j occurs? If true the appropriate signed interaction is entered in the β or proportional impact matrix.
2. Does x_i change even though x_j is not changing? If true, the class is accumulative and the appropriate entry is made in the α or cross-impact matrix.
3. Note that the algorithm allows for both classes of causality to exist between variables simultaneously. If this occurs an entry is made in both the α and β matrices.

The magnitude of the initial matrix entries is not critical for first runs and are obtained by such means as

1. Assigning a scale of values to the meaning of weak, moderate and strong interactions, e.g. ± 1, ± 3, ± 9, etc.
2. Knowledge of a functional relation expressed analytically that can be used to compute an interaction coefficient.
3. By considering only the sign of the interaction using ternary entries +1, 0, -1.

After the model is specified, participative modification of the magnitudes is performed by the user until he has a satisfactory understanding of the dynamics possible for "his" model.

C. Augmentation of the KSIM Algorithm - GSIM

The Geometric Simulation Model (GSIM) is an augmentation of the basic KSIM algorithm to include delays, dynamic modification of the α and β matrices through rate and level threshold sensing, and provision for driving the model with external data. To realize all features of the GSIM algorithm the following data requirements must be met. If only the KSIM requirements are met (denoted (*)) the algorithm produces results identical to the KSIM algorithm. This makes it possible for the user to begin with a simple KSIM model and to extend the model to a more complex representation in a straightforward manner.

i) GSIM Requirements:

*1. A set of variables is specified.

*2. A set of initial values for the variables and/or their derivatives is specified.

*3. A cross-impact (α) matrix and/or a proportional-impact (β) matrix is specified.

4. Rate thresholds and/or level thresholds, direction of threshold penetration, and operational matrices affecting α or β are specified.

5. A delay matrix is specified.

6. External data is specified for the duration of the simulation.

ii) GSIM Procedural Steps:

Step 1: Test all specified variable thresholds. If a threshold is penetrated initially in the direction specified, add the relevant operational matrix element by element to the specified α or β matrix as specified.

Step 2: For each variable compute an exponent using the KSIM method, however, the values participating are the $x_j(N-d_{ij})$ where d_{ij} is the specified number of iterations of delay specified in a delay matrix. Note also that $x_j(N-d_{ij})$ does not affect x_i until the number of iterations exceeds d_{ij}, thereafter the values delayed by d_{ij} iterations participate in the computation of $P_i(T)$. If d_{ij} is 0, no delays in impact occur.

Step 3: Determine if any $x_i(T)$ has a value specified externally for $x_i(T+DT)$. If so, compute a $P_i'(T)$ for $x_i(T)$ based upon the previous external values $x_{iE}(T)$ and $x_{iE}(T+DT)$ by $P_i'(T) = \log_{10}x_{iE}(T+DT)/\log_{10}x_{iE}(T)$. (8)

Step 4: Compute all $x_i(T)^P$ using as an exponent either $P_i(T)$ if no external data was supplied, or a resultant P from $P_i(T)$ and $P_i'(T)$ if external data was supplied. Note the following concerning x(T+DT) and x(T) as P takes values less than, equal to or greater than one recalling that $0 \leq x(T) \leq 1$.

$0 < P < 1$, $x(T+DT) > x(T)$ (an increase)
$P = 1$, $x(T+DT) = x(T)$ (no change)
$P > 1$, $x(T+DT) < x(T)$ (a decrease)

If external data has been supplied for x(T) and x(T+DT) and this variable is also impacted by the system, two exponents are computed. One exponent $P_i(T)$ is computed using all current values for all x_i. A second exponent is computed using the external data supplied for $x_{iE}(T)$ and $x_{iE}(T+DT)$. If both $P_i(T)$ and $P_i'(T)$ are less than one, a resultant P is computed that will be still smaller than either $P_i(T)$ or $P_i'(T)$ but greater than zero using the relation

$$P = P_i(T) \cdot P_i'(T) \qquad (9)$$

and the resultant P will increase $x_i(T)$ faster than would be caused by either independently. If one exponent is less than unity and the other greater than unity, the result is to reduce the effect either would have independently. If both are greater than unity, the resultant P will be greater than either and $x_i(T)$ will decrease faster than either exponent would cause independently. Obviously if the system does not impact the variable $x_i(T)$ with externally supplied data, $P_i(T)$ will be unity and $P = P_i'(T)$ leaving $x_{iE}(T+DT) = x_i(T+DT)$.

Step 5: Iterate steps 1, 2, 3, and 4 until the specified number of iterations is achieved.

Appendix II

On the Relationship Between KSIM and System Dynamics

This appendix essentially compares the manner in which causality is perceived, interpreted, and characterized for the methodologies due to Kane and Forrester. The discussion is limited to just these two methodologies because of the significant role each assumes in the modeling of socio-economic systems. The intent of the two approaches is similar -- each endeavors to characterize the causality resident within a process or system by means of a causal model, and to extract the behavioral consequences implicit within that causal model. But the approach that is taken and the assumptions regarding causality inherent within each are quite different as shall be discussed in the sequel.

Before considering the manner in which each method characterizes causality, some qualitative and descriptive statements about each method are appropriate. The KSIM approach is a policy-maker participatory procedure. The basic idea is to allow the policy makers themselves to determine (through consensus) the structure of the actual system, using cross-impact concepts. KSIM then employs this structure as part of a fixed algorithm within the computer's memory which extracts the behavioral implications of the structure. The panel of policy makers are allowed through a time-sharing terminal to manipulate and change the structure until it is believed and understood. Then the affects of alternate policies are examined in terms of their relative behaviors and the most appropriate policy can be selected based upon the comparison of the plotted consequences. Other researchers extended or modified KSIM to add sophistication and increase the capabilities of the Kane methodology [19,20].

The system dynamics approach, on the other hand, is an off-line procedure in which a modeler collects and collates the necessary information to construct a simulation model whose structural format is general and is not limited to the fixed sigmoid model used in KSIM. While more comprehensive and thorough than KSIM, system dynamics does not possess KSIM's policy-maker participatory feature which enhances credibility of the model.

Both methods have an established record of usefulness and are employed in slightly different contexts -- system dynamics being preferred when time and financial resources permit, whereas KSIM is preferred when either of these resources is limited or when group consensus is a significant issue.

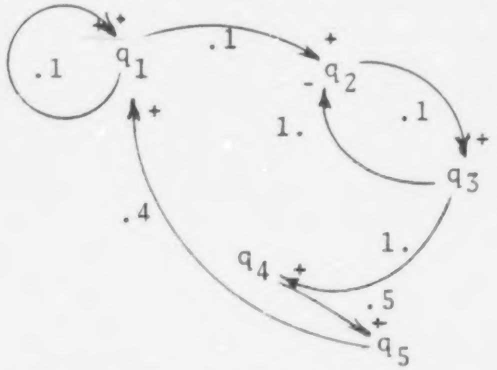
A. The Characterization of Causality

Each of the two methodologies being compared here employs a different scheme for characterizing or representing causality within socioeconomic systems. KSIM applications exhibit a tendency to use the cross-impact matrix, whereas system dynamics users make expeditious use of the causal diagram. Both approaches are closely related as shall shortly be observed.

Kane-style procedures [4,19,20] for modeling systems require only that the user specify a set of quantities Q, a set of interactions or couplings C between any two pairs (q_i, q_j) defined on

Q x Q, and a set of initial conditions for each of the quantities q_i and denoted by q_o. Thus, the triplet $\{Q,C,q_o\}$ constitutes the minimum specification requirement for any Kane-like methodology. The specification of Q is usually accomplished by means of brain-storming techniques and usually does not exceed twenty or so elements. The specification of C is performed by filling the associated interaction (or cross-impact) matrix $M(=\{m_{ij}\})$. Thus, if quantity q_j is thought to have an affect on quantity q_i, an entry is placed in the $m_{ij}{}^{th}$ position of the matrix M representing the strength and sign of the affect.

Corresponding to every matrix M is a causal or structural model which graphically depicts all of the interactions indicated in M. In fact, M bears close resemblance to the transpose of the "adjacency matrix" discussed in graph theory [21]. A hypothetical causal model and its associated interaction matrix M are shown in Figure 1 below. (Blank positions are interpreted as zero and represent the nonexistence of a causal interaction between two associated quantities.) Thus, an entry in m_{jk} represents the extent and sign of the effect of q_k upon q_j.

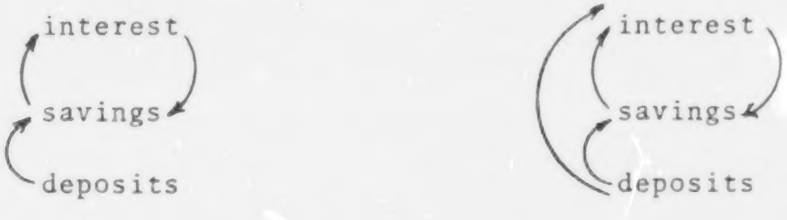


$$\begin{array}{c|ccccc} & 1 & 2 & 3 & 4 & 5 \\ \hline 1 & .1 & & & & .4 \\ 2 & .1 & & -1. & & \\ 3 & & .1 & & & \\ 4 & & & 1. & & \\ 5 & & & & .5 & \end{array}$$

Figure 1: Hypothetical Causal Model and Associated Cross-Impact Matrix M.

Unfortunately, many applications of Kane-like procedures do not make judicious use of the structural model to facilitate specification of the matrix M. The causal diagram approach to structural modeling, as employed in the system dynamics methodology is still a very useful technique for assisting with the specification of the set of couplings C. Even though Kane makes no use of the technique, it is easy to demonstrate its inherent usefulness as a cognitive and communication device.

Moreover, the causal diagram pictorially illustrates the paths of 'causal reachability'. This pictorial representation helps to eliminate paths of reachability which are superfluous and clearly not realistic. If the interaction matrix M is specified without also considering the associated causal diagram, too little attention is given to paths which are redundant. For example, consider the relationship between deposits, savings, and interest. Do deposits have an affect on interest? Clearly, the response is affirmative, but the affect is through savings.



(a) (b)

Figure 2: Conceivable Causal Relationships Between Interest, Savings, and Deposits

Figure 2 shows two conceivable causal relationships between interest, savings, and deposits. In Figure 2a the affect of deposits upon interest is through savings. In Figure 2b there are two paths by which interest may be reached from deposits. In this case, the path of causal reachability from deposits to interest is through savings, and the direct path from deposits to interest is superfluous. However, without the use of the causal diagram, the user would be inclined to place an entry in the location which reflects the affect which deposits have on interest.

Consider the interaction matrix below.

	deposits	savings	interest
deposits	m_{11}	m_{12}	m_{13}
savings	m_{21}	m_{22}	m_{23}
interest	m_{31}	m_{32}	m_{33}

Figure 3: Interaction Matrix for the Three Quantities Shown

Corresponding to entry m_{31}, there is a temptation to insert a number other than zero reflecting the influence which deposits have on interest. However, no entry other than zero is causally correct, as the affect of deposits upon interest is realistically modeled by the affect of deposits upon savings and of savings upon interest. This would be indicated in the cross-impact matrix by nonzero entries in positions m_{21} and m_{32}. This argument is sufficient to establish the claim that drawing the causal model helps the user establish paths of causal reachability and eliminate interactions which are redundant or superfluous.

While the causal diagram can be a useful aid in the avoidance of errors of commission, its delineation should perhaps not be performed until after the user has systematically considered every entry in the cross-impact matrix M and entered an appropriate response. Kane, et.al.[6] acknowledge "a great benefit in going through the full bookeeping of all pairings of variables". The setting of an entry in the interaction matrix M to zero should, he maintains, be a deliberate conscious act so as to avoid overlooking an important link in a feedback loop. Such a procedure would avoid possible errors of omission which an unsystematic and uncomprehensive procedure is likely to commit.

B. The Classification of Causality

Once the causal interactions between the elements of a system have been identified, the next step is to classify each individual interaction as belonging to a specific class of deterministic causality. Both Forrester and Kane recognize exactly two specific types of causal interactions. In the system dynamics literature these are referred to as the information path and the flow path [7]. In the KSIM literature the reference is to long term (constant) and short term (or derivative) affects [6]. These respective classes in the two methodologies will, in the sequel, be shown to be equivalent.

In the long term constant causal relation, a quantity q_i accumulates the net effect of an affecting quantity q_j (in the monovariate case). Causal relations of this type are generally represented by the following differential equation:

$$\dot{q}_i \equiv \frac{dq_i}{dt} = \alpha_{ij}q_j, \quad q_i(t_o) = q_{io} \qquad (1)$$

where α_{ij} is the interaction coefficient, or more generally by

$$\dot{q}_i = f(q_j), \quad q_i(t_o) = q_{io} \qquad (2)$$

where $f(q_j)$ is an explicit function of q_j. From Eqs. (1) and (2) it is clear that q_i accumulates the affect of q_j, as $q_i(t) = q_{io} + \int_{t_o}^{t} f[q_j(\tau)]\, d\tau$. Note that even if the independent quantity q_j were to remain constant the dependent quantity q_i is changing as it accumulates the affect of q_j. The mere presence or existence of q_j produces change in q_i. In terms of behavior, any quantity q_i which accumulates the affect of some quantity q_j through a function $f(\cdot)$ will monotonically increase as long as $f(\cdot)$ is positive, and will monotonically decrease once $f(\cdot)$ becomes negative.

Examples of this type of causality abound. The relationships of petroleum reserves to petroleum consumption, of savings to compounded interest, of inventory to received shipments and sales, of population to births and deaths, of food to food generation and food consumption are all of this type. In each case, the former quantity accumulates the affects of the latter quantity (quantities).

The nature of the equivalence between the long-term constant relation of KSIM and the flow path concept of system dynamics is apparent just from observation of Eq. (2) and its associated level equation:

$$q_i(t+\Delta t) = q_j(t) + \Delta t\{f(q_i)\}.$$

In system dynamics, whenever there is a flow taking place, there must also be a level variable into which the net flow can accumulate, since the level equation is just a simple accounting of the net accumulation that has taken place over a certain period of time [13, p.76].

The second type of causality considered by Kane is the short-term derivative impact in which an affected quantity q_i is related to its affecting quantity q_j by means of a causal relation of the form

$$\dot{q}_i = \beta_{ij}\dot{q}_j. \qquad (3)$$

Since β_{ij} is a constant, both sides of this equation can be integrated to yield

$$q_i = \beta_{ij}q_j + \eta, \qquad (4)$$

where η is the constant of integration. Eq. (4) suggests that q_i is proportional to q_j. For the monovariate case the general form of a short-term derivative impact is given by $q_i = g(q_j)$. The behavior of an affected quantity q_i which is the dependent variable in a short-term derivative impact is one of growth if the change in $g(q_j)$ is positive, decay if the change is negative, and stationarity if there is no change in q_j as time advances.

Such behavior is fully analogous to the behavior resulting from two quantities q_i and q_j which interact by means of an information path in the system dynamics sense. Information links connect levels to rates sometimes via auxiliaries [7, p.9-3, 9-4]. In the monovariate case, the functional form of the associated rate or auxiliary equation is $q_i = g(q_j)$. Thus the short-term derivative impact is equivalent to the information path concept of system dynamics.

To complete the specification of the causal relations represented by Eqs. (1) or (3), it is necessary only to specify the constants α_{ij} and β_{ij}.

For the multivariate case involving n quantities q_i the linear relationships (1) and (3) assumed by Kane become $\dot{q}_i = \sum_{j=1}^{n} \alpha_{ij} \cdot q_j$ and $q_i = \sum_{j=1}^{n} \beta_{ij} \cdot q_j + \eta$, where $\{\alpha_{ij}\}$ and $\{\beta_{ij}\}$ are the elements of n x n matrices A and B respectively.

Kane then recognized that, in theory at least, it is possible for a particular quantity q_i to be affected by long-term and short-term impacts simultaneously. This suggested the need for combining the two multivariate equations into a single equation. Diffentiating $q_i = \sum_{j=1}^{n} \beta_{ij} \cdot q_j + \eta$ yields $\dot{q}_i = \sum_{j=1}^{n} \beta_{ij} \cdot \dot{q}_j$. Combining this with the long-term multivariate relation precipitates the following equation, which we shall refer to as the unmodulated Kane form:

$$\dot{q}_i = \sum_{j=1}^{n} \alpha_{ij} q_j + \sum_{j=1}^{n} \beta_{ij} \dot{q}_j \text{ , } i=1,2,\ldots\ldots,n; \qquad (5)$$

$$q_i(t_o) = q_{io}$$

The associated vector-matrix format is simply, $\dot{q} = Aq + B\dot{q}$, $q(t_o) = q_o$, in which q is an n-vector defined on an n-dimensional Euclidean space. Eq. (5), when multiplied by Kane's modulation function [6], $-q_i \ln q_i$, yields the Kane formulation:

$$\dot{q}_i = \{ \sum_{j=1}^{n} \alpha_{ij} \cdot q_j + \sum_{j=1}^{n} \beta_{ij} \cdot \dot{q}_j \ (-q_i \ln q_i), \ i=1,2,\dots,n, \quad (6)$$

$$q_i(t_o) = q_{io} \ .$$

This is to be contrasted with the more general Forrester form involving a combination of the two general causal relations $\dot{q}_i = f(q_j)$ and $q_i = g(q_j)$, which for the multivariate case involving n quantities, becomes

$$\dot{q}_i = f_i(q_1, q_2, \dots, q_n), \ q_i(t_o) = q_{io}$$

or (7)

$$q_i = g_i(q_1, q_2, \dots, q_n), \ i=1,2,\dots,n.$$

Here, each of the n quantities q_i is prescribed by one of the two Eqns. (7a) or (7b). Quantities q_i which accumulate the long-term impacts of other quantities and whose equation form is given by Eq. (7a) above are referred to as "levels" and shall here be denoted by x_i. Quantities q_i which enter into short-term derivative impacts and whose equation form is given by Eq. (7b) are referred to as rates or auxiliaries. Auxiliaries shall herein be identified by y_i. Since the net sum of all rates affecting a level x_i is simply $\dot{x}_i$, the rates do not explicitly appear in a functional representation of the form of Eq. (7).

Using the notation just described for levels and auxiliaries, and including an additional quantity type for parameters (constants) p_i, Eq. (7) can be rewritten in vector format as follows:

$$\dot{x} = f[x(t),y(t),p], \quad x(t_o) = x_o$$

and (8)

$$y = g[x(t),y(t),p].$$

Here, p is a vector of parameters, y is the vector of auxiliary variables, and x is the vector of state variables. The vector auxiliary equation $y = g(x,y,p)$ gives the mistaken impression that the auxiliaries are implicit functions of themselves, states, and parameters; however, the rules of system dynamics require the auxiliaries to be explicit functions of other auxiliaries[1], states, and parameters -- through algebraic elimination it would be possible to rewrite $y = g(x,y,p)$ as $y' = g'(x,p)$.

Now the problem of how to distinguish between these two forms arises. Impacts of the form $q_i = \beta q_j$ are immediate, almost instantaneous: a change in q_j produces an instantaneous change in q_i. Impacts of the form $\dot{q}_i = \alpha q_j$ are longer term in that time is involved in order for q_i to accumulate the affects of q_j. These are considerations to bear in mind when the linkages in the causal model are interpreted. Each linkage must be considered separately using the following criterion:

---

[1] Although auxiliaries can be functions of other auxiliaries, a feedback loop consisting entirely of auxiliaries is forbidden [4, p.78]. The consequence of this requirement is that auxiliaries cannot be implicit functions of themselves.

let the "affecting" quantity q_j remain constant -- does the affected quantity q_i continue to change as time is advanced as a result of the coupling (q_j,q_i)? If so, the proper interpretation is $\dot{q}_i = \alpha q_j$. However $\dot{q}_i = \alpha q_j + \beta \dot{q}_j$ is also possible under this condition. On the other hand, if the result of the test suggested above is clearly negative, then the only correct interpretation is $q_i = \beta q_j$.

One is inclined to wonder if there are classes of deterministic causality overlooked by the two methodologies being considered [9]. What about monovariate causal relations of the form $\ddot{q}_i = \gamma_{ij} q_j$, or more generally $\overset{n}{q}_i = \delta_{ij} \overset{n-1}{q}_j + \xi_{ij} \overset{n-2}{q}_j + \ldots. + \omega_{ij} q_j$? It can be shown that all such linear n^th^ order differential equations can be transformed into n first-order differential equations [22, p.251]. Consequently, the absence of consideration to this structural form constitutes no loss of generality. However, such is not the case for monovariate causal relations of the form $q_i = \theta_{ij} \dot{q}_j$ or more generally $q_i = \phi_{ij} \overset{n}{q}_j + \rho_{ij} \overset{n-1}{q}_j + \ldots. + \nu_{ij} \dot{q}_j$. In system dynamics such relations are possible when q_i is a quantity upon which no other endogenous quantity q_j is dependent.

C. The Conjectures of Causality

In this section, the two formulations developed in the previous section are examined with the intent of discerning what conjectures of causality underlie each. Consider a linear rendition of the Forrester formulation expressed by Eq. (8) in which the dependence upon the parameter vector p is omitted from the vector level equation $\dot{x}$ for convenience.

$$\begin{aligned} \dot{x} &= A^{\dagger} x + C^{\dagger} y \quad , \; x(t_o) = x_o \\ y &= B^{\dagger} x + D^{\dagger} y + E^{\dagger} p. \end{aligned} \qquad (9)$$

Here the matrices $A^{\dagger}$, $C^{\dagger}$, $B^{\dagger}$, and $D^{\dagger}$ contain no elements which are functions of time. Eq. (9a) above simply expresses the well established maxim that rates, $\dot{x}$, are functions of levels and auxiliaries [7, p. 4-10], whereas Eq. (9b) expresses the precept that auxiliaries are functions of states, other auxiliaries, and parameters [13, p. 78]. Now the rules regarding formulation of auxiliaries impose restrictions upon the insertion of entries into the matrix $D^{\dagger}$. In particular, all diagonal entries within $D^{\dagger}$ must be zero, as an auxiliary cannot be a function of itself. In addition, entries within $D^{\dagger}$ should not permit a cycle or loop involving exclusively auxiliary variables. Through rearrangement of the ordering of the auxiliary variables in the vector y it is possible to obtain a $D^{\dagger}$ matrix in which all nonzero entries appear below and to the left of the main diagonal, provided the rules stated above are properly preserved. Matrices $D^{\dagger}$ which are lower-left triangularizable are herein called proper.

Let us differentiate Eq. (9b) to obtain the following system of equations.

$$\begin{aligned} \dot{x} &= A^{\dagger}x + C^{\dagger}y, \; x(t_o) = x_o \\ \dot{y} &= B^{\dagger}x + D^{\dagger}\dot{y}, \; y(t_o) = (I-D^{\dagger})^{-1}(B^{\dagger}x_o + E^{\dagger}p) \end{aligned} \qquad (10)$$

By defining

$$q = \left\{ \frac{x}{y} \right\}, \; A = \left[\begin{array}{c|c} A^{\dagger} & C^{\dagger} \\ \hline 0 & 0 \end{array}\right], \quad B = \left[\begin{array}{c|c} 0 & 0 \\ \hline B^{\dagger} & D^{\dagger} \end{array}\right] \qquad (11)$$

it is a simple exercise to show that Eq. (10) can be rewritten as

$$\dot{q} = A\,q + B\,\dot{q}, \quad q(t_o) = q_o = \begin{Bmatrix} x_o \\ (I-D^+)^{-1}(B^+x_o + E^+p) \end{Bmatrix} \quad (12)$$

Now consider the unmodulated Kane-form given by Eq. (5): it is observed that Eq. (12) is just the vector-matrix representation of Eq. (5) in which $A = \{\alpha_{ij}\}$, and $B = \{\beta_{ij}\}$.

These arguments are sufficient to establish the following theorem.

Theorem 1: A linear Forrester-style model given by Eq. (9) is transformable into the unmodulated Kane-form $\dot{q} = Aq + B\dot{q}$, using the definitions provided in Eq. (11).

The corollary to this theorem is also readily verifiable using Eqs. (9, 11, and 12).

Corollary 1: Any unmodulated Kane-form $\dot{q} = Aq + B\dot{q}$, whose quantity vector q and matrices A and B can be partitioned as indicated in Eq. (11) and whose precipitant D^+ matrix is proper, can be transformed into a linear Forrester-style model given by Eq. (9).

Proof: The proof follows directly from the matrix multiplications implied by $\dot{q} = Aq + B\dot{q}$ when the definitions provided by Eq. (11) are substituted.§

Next the conditions under which the unmodulated Kane-form $\dot{q} = Aq + B\dot{q}$ is partitionable into the format required by Eq. (11) and the matrix D^+ resulting therefrom is lower-left triangularizable with zero diagonal entries is related. Clearly, from Eq. (11) any quantity q_i with nonzero entries in A must have entirely zero entries in B. This is equivalent to the requirement that all of the causal interaccions directed toward a particular quantity are of the same type. Such quantities are called consistent.

Secondly, consistent quantities which are involved in short-term (proportional) interactions cannot be proportional to themselves, either directly or indirectly. Thus, they must not be included in any loops or cycles involving exclusively other quantities which are affected by short-term derivative interactions. Quantities which do not participate in their own short-term, proportional impacts either directly or through elimination of certain intermediary variables are said to be self-disjoint because they are not proportional to themselves.

The following theorem describes the conditions under which the unmodulated Kane-form is partitionable as suggested by Eq.(11) with a resultant D^{+} that is proper.

Theorem 2: Any unmodulated Kane-style model whose quantity set Q consists exclusively of quantities q_i which are consistent and self-disjoint is capable of being partitioned into the form specified by Eq. (11), precipitating a D^{+} that is proper.

Proof: The partitionability of the quantities q_i into states and auxiliaries as required by the form of Eq.(11) is achievable when each of the quantities q_i is consistent, whereas the matrix D^{+} will be proper whenever the quantities q_i are self-disjoint. In terms of the matrix B, the condition of self-disjointness requires that all entries along the diagonal of B be zero. In addition, it requires the matrix B to be lower-left triangularizable. Clearly from Eq.(11) if B is lower-left triangularizable with zero entries along the diagonal, then D^{+} must possess these properties as well.

We refer to matrices $D^{\dagger}$ which retain such properties as being proper.§

The following theorem stipulates the conditions under which Kane-style models are translatable to Forrester-style models.

Theorem 3: Any unmodulated Kane-style model whose quantity set Q consists entirely of quantities q_i which are consistent and self-disjoint is transformable into a linear Forrester-style model of the form Eq. (10).

Proof: The proof is a simple deductive consequence of theorem 2 and corollary 1.§

The relationship between the unmodulated Kane-form given by Eq. (5) and the linear Forrester form, Eq. (9), being addressed here makes emphatic the distinctions amongst the two methodologies insofar as conjectures about causality in socioeconomic systems is concerned. In particular, it has been observed that Kane's methodology implicitly assumes all of the following postulates regarding causality are possible, whereas the Forrester methodology disallows all of them.

1) A quantity q_i which is coupled to and dependent upon a quantity q_j can (may) interact with q_j by means of more than one type of causality at any one instant, as indicated by the equation $\dot{q}_i = \alpha_{ij}q_j + \beta_{ij}\dot{q}_j$.

2) A quantity q_i may be proportional to itself either directly or indirectly, as indicated by the expression $\dot{q}_i = \beta_{ii}\dot{q}_i$.

3) A quantity q_i which is coupled to and dependent upon several quantities q_j and which is simultaneously affected by all of them as time advances, can be related to the different quantities q_j by means of different types of causality, as indicated by a relation of the form $\dot{q}_i = \alpha_{ij}q_j + \beta_{ik}\dot{q}_k + \beta_{im}\dot{q}_m$.

Postulates (1) and (3) are disallowed by the consistency property, whereas postulate (2) is disallowed by the condition of disjointness. Apparently the Kane methodology, even though its prescribed sigmoid behavior is very restricted, offers increased flexibility in terms of the characterization of causality. The added flexibility may cause "errors of commission" to appear in the causal structure. In any case, the delineation of a causal diagram combining the interactions indicated in the matrices A and B would be very revealing.

This is not to say that one methodology is more flexible or less restricted than another. The analysis merely indicates that the methodologies are applicable to different problem classes within socioeconomic systems, giving rise to the need for a proper description of the problem class to which each is appropriate. At this time it seems fair to assert that KSIM-like approaches are applicable to problems in which the postulates described above may occur, whereas system dynamics is not. The utilization of the added flexibility does carry with it, however, added responsibility to ensure that links are not inserted which do not represent reality.

Appendix III

(A full documentor listing of the formal Forrester simulation computer program follows.)

The logic of the simulation computer program is patterned after the format shown in Figure 4 below and employs the FORDYN package for software support. The host language is FORTRAN IV. The FORDYN package provides routines for printing, plotting, for representation of table functions, delays, and array specification. The line sectors of the model are all implemented within the main program.

The general format of MAIN is shown below and consists of three parts. In part 1, declaration of subscripted variables, equivalence, and data statements comprise the nonexecutable portion. This is followed by executable statements which initialize parameters, inputs, states, and control variables (NT, NK). Finally, preparations are made for printing and plotting through successive cells to PERP.

Part 2 performs the actual simulation by advancing the independent variable TIME in small equidistant steps DT and utilizing simple Enter integration formulas. At each time point the auxiliary and rate variables are computed, using their associated equations and the values of the state variables at the time point. Then the state variables are 'predicted' to the next time point using an Enter predictor formula and the whole process is repeated. Two rest DO-loops are used instead of one in order that printing and plotting take place on every NK^{th} interation instead of every integration step DT. Successive calls to OUTP perform the necessary storage of variables for later plotting.

In part 3 of the program the values of these quantities which were stored in the second part of the program are plotted. Stated succinctly, the three parts are 1) initialization, 2) execution (of the simulation), and 3) plotting.

```
                    REAL.....
                    DIMENSION.....
                    .
                    .
                    .
                    NT=
                    NK=
PART 1              A=
                    X=
                    Y=
                    DT=
                    TIME=
                    .
                    .
                    .
                    CALL PREP( .......)
                    DO 10 I=1, NT
                    IF(I.EQ.1)GO TO 30
                    DO 20 J=1, NK
                       (state equations)
                       .
                       .
                       TIME=TIME+DT
             30        A=X+Y**2 (1st auxiliary equ.)
                       .
                       .
                       .
PART 2                 (auxiliary equations)
                       .
                       .
                       .
                       (rate equations)
                       .
                       .
                       .
                    R=A+X**2
                    IF(I.EQ.1)GO TO 40
             20     CONTINUE
             40     CALL OUTP(....... )
             10     CONTINUE
                    .
                    .
                    CALL PLOT(NT, .)
PART 3              .
                    .
                    .
                    STOP
                    END
```

Figure 4: Format Employed for Implementation of the Forrester-style Rehabilitation Model

```
      REAL IDISE,IDISI,IDISP
      REAL LIFEFN(7,14),TECHNO(5,14,20),PTOT(15),ALF(7),DLFIN(7,14),
     1 RRT(15),DOLARS(5,14,20),ALFOM(7),PTODM(15),COSTPC(14,20),
     2 DLFFN(7,14),ART(15),LFAR(7,14),DLFNET(5,14),APPDCL(5,14,20)
      REAL POPDU(15,14,2),DRN(15,14,2),RRN(15,14,2),ARN(15,14,2),
     1      BRN(15,2),PREV(15),DR(15,14,2),RR(15,14,2),AR(15,14,2),
     2BR (15,2),PTOTU(15),AAA(14,2),BBR(14,2),CONSE(10),CONSEP(10)
      INTEGER LINE(118),B/' '/,LLL/'<'/,R/'>'/,AGES(14,4),S/'|'/,
     1         T1/'T'/,T2/'O'/,NAMES(23,6),Z/1/,ZERO/'0'/
      REAL GNNP,GP(3),GDP(2),UNCR,GTR,EUR,NNP,P,DP,TR,UN,E,V(6),VP(6),
     1  DV(6),U(6),UP(6),W(6),WP(6),DU(6),GE1(2),GE2(2),DSEMLF(5),
     2DW(6),SDFR,REFR,TAXR,PRODPC,EWFR,GNPR,TAX,TAXG,
     3REWMC(6),REFMC(6),REDPMC(6),PROFND(8),PROFNP(8)
      EQUIVALENCE(V(1),NNP),(V(2),P),(V(3),DP),(V(4),TR),(V(5),UN),(V(6
     1  ,E),(CAP,U(1)),(WW,U(2)),(WI,U(3)),(WT,U(4)),(CI,U(5)),(CT,U(6)
      EQUIVALENCE (FACGEN,FACABL)
      EQUIVALENCE (ADAPTD,CONSE(1)),(DISI ,CONSE(2)),(FACDBL,CONSE(3)),
     1 (DISS,CONSE(4)),(PEREN,CONSE(5)),(RRATE,CONSE(6)),(PREAC,CONSE(7
     2),(FACABL,CONSE(8)),(DISP,CONSE(9)),(DISE,CONSE(10)),(TMDS,PROFND
     38))
      DATA N6,N7,N8,N9,N10 /6,7,8,9,10/
      DATA TECHNO /1400*.1/,APPDCL /1400*1./,COSTPC /280*1./,LFAR
     1  /98*1./,LIFEFN /98*1./,DLFFN /98*1./
      DATA N1,N2,N3,N4,N5,NV,TIMEF/1,2,3,4,5,6,2025./
      DATA POPDU /420*1./,ALFOM /7*0./,PTODM /15*0./
      DATA ARN /420*0./,RRN/420*0./ ,CONSE/10*0./,PROFND/08*0./
   29 FORMAT(80A1)
  361 FORMAT(8F10.5)
   31 FORMAT(18A4)
C
C CONSEQUENCE SECTOR AND PROGRAM SECTOR CONSTANTS AND PARAMETERS
C
      DISEM = 61.5
      DISIM = 5000.
      DISPM = .2
      DISSM = .1
      PREAC = .3
      AECONV  = .01
      PIFP = .35
      ECFP = .20
      TCFP = .30
      SDFP = .15
      DISSM = DISSM * 100. / 61.
      DISIM = DISIM*100. / 61.
      RRIT = 400000.
      RRRT = 300000.
      DISPM = DISPM * 100. / 61.
      FUNDSD = 1E9
      FUNDSG = 1E9
      FACDOB = 1./30.
      AYRL = 45.
      AYRW = 35.
      AAI = 12500.
      PRW = 61.5
C
C MISCELLANEOUS CONSTANTS TO CONTROL PROGRAM OPERATION
C
      ICOUNT = 1
      DO 40 J=1,MM
      DO 40 K=1,2
   40 PTOTO(I)=PTOTO(I)+POPDU(I,J,K)
      DO 42 I=1,14
      LIFEFN(1,I) = .4
      LIFEFN(2,I) = .5
      LIFEFN(3,I) = .3
      LIFEFN(4,I) = .45
   42 LIFEFN(5,I) = .35
      DO 55 I=1 ,14
      DO 55 M=1,20
   55 COSTPC(I,M)=1.
      DO 56 I=1,14
      DO 56 L=1,7
   56 LFAR(L,I)=LIFEFN(L,I)
      DO 44 L=1,5
      SUM=0.
      DO 43 I=1,KK
   43 SUM=SUM+PTOTO(I)*LIFEFN(L,I)
      SUM=SUM+PTOTO(15)
   44 ALF(L)=SUM/P
      ALF(6)=0.
      ALF(7)=0.
1     FORMAT(8F10.0)
4     FORMAT(8E10.0)
      DO 100 I=1,6
      DU(I) = 0.
      DW(I)=0.
  100 DV(I)=0.
      TIMS = 0.
      TIMPER = 50.
      TIMPER = 40.
      NT = TIMEF - TIME
      NT    = NT + 1
       NK = 1./DT +.01
      NT = 44
      NK = 8
C
C INITIALIZE CONSEQUENCE SECTOR STATES
C
      ADAPTO = 0.
      ADVOC = 0. .
      FACORL = 19815000.
      DISS = 0.
      PEREN = 0.
      RRATE = 50000.
      PREAC = 0.
      FACARL = .1123E9
      DISP = .2
      DISE = .4
      IDISE = 0.
      IDISI = 0.
      IDISP = 0.
      FACDIS = 1E11
      PEREN = .6
      FACGEN = 1E12
C
C INITIALIZE PROGRAM SECTOR STATES
```

```
      ICOHRT = 0
      IJMP = 0
      IJMP = 1
      NCAT = 15
      NN = NCAT
      KK = NN-1
      EX = 5.
      MM = 14
      LL = MM - 1
C
C READ-IN ALL NECESSARY DEMOGRAPHIC STATISTICS
C
      READ(4,28) ((AGES(I,J),J=1,4),I=1,MM)
      READ(4,31) ((NAMES(I,J),J=1,6),I=1,23)
      READ(4,1) (((POPDU(I,J,K),K=1,2),J=1,MM),I=1,NN)
      READ(4,1) (((DRN(I,J,K),K=1,2),J=1,MM),I=1,NN)
      READ(4,1)  ((BRN(I,J),J=1,2),I=1,NN)
      READ(4,361)  PREV
      IF(IJMP.EQ.1) GO TO 63
C
C READ-IN LIFE-FUNCTION STATISTICS INDEXED BY DISABILITY
C
      READ(4,1) ((DLFFN(L,I),L=1,7),I=1,14)
      READ(4,1) ((LIFEFN(L,I),L=1,7),I=1,14)
      READ(4,1) ((LFAR(L,I),L=1,7),I=1,14)
C
C READ-IN DATA ON TECHNOLOGIES
C
      READ(3,1) (((TECHNO(L,I,M),L=1,5),I=1,14),M=1,20)
      READ(3,1) (((APPOOL(L,I,M),L=1,5),I=1,14),M=1,20)
      READ(3,1) ((COSTPC(I,M),I=1,14),M=1,20)
   63 CONTINUE
      DO 10 ISCEN = 1,4
C
C ISCEN IS THE SCENARIO INDEX:
C               ISCEN = 1 GIVES SCENARIO MGFS
C               ISCEN = 2 GIVES SCENARIO AGFS
C               ISCEN = 3 GIVES SCENARIO RGFS
C               ISCEN = 4 GIVES SCENARIO ADFS
C
C
C READ-IN SCENARIO DATA AND INITIALIZE SCENARIO STATES FOR THE YEAR 1940
C
      READ(5,1) REWMC
      READ(5,1) RECMC
      READ(5,1) REPMC
      READ(5,4) V,TIME,DT
      READ(5,4) U
      READ(5,4) W
      READ(5,4) TAX
      READ(5,1) GNNP,GP,GDP,UNCR,GTR,FUR,GE1,GE2
      READ(5,1) SDFR,REFR,TAXS,EWFR
C
C INITIALIZE TOTAL POPULATION FOR EACH DISABILITY, COSTS, INITIAL LIFE
C FUNCTIONS, ETC., ETC., ETC.
C
      DO 40 I=1,NN
      PTOTC(I)=0.
```

```
C
      TRANSP = 2.
      AMEDPA = 1.
C
C SUCCESSIVE CALLS TO PREP MAKES PREPARATIONS FOR PRINTING AND PLOTTING
C
      CALL PREP(U,UP,NV,8,1,1,0,0)
      CALL PREP(W,WP,NV,9,1,1,0,0)
      CALL PREP(ALF,ALFCM,7,10,1,1,0,0)
      CALL PREP(PTOTO,PTOOM,15,11,1,1,0,0)
      CALL PREP(CONSE,CONSEP,10,12,1,1,0,0)
      CALL PREP(PROFND,PROFNP,8,14,1,1,0,0)
      CALL PREP(V,VP,NV,7,1,1,0,1)
      DO 7 II=1,NT
      IF(II.EQ.1) GO TO 3
      DO 5 JJ=1,NK
C
C LEVEL EQUATIONS-SCENARIO SECTOR
C
      DO 2 K=1,6
      U(K) = U(K) + DT * DU(K)
      W(K)=W(K)+DT*DW(K)
2     V(K) = V(K) + DT * DV(K)
      TAX=TAX+DT*TAXR
      IF(TIME.GE.1974.) GO TO 99
      V(5)=W(N5)*0.051
      GO TO 999
   99 V(5) = JNCR*W(N5)
  999 IF(TIME.LT.2000..OR.ISCEN.EQ.3) V(N3) = .146 * V(N2)
      IF(TIME.LT.2000..OR.ISCEN.EQ.4) V(N3) = .146 * V(N2)
C
C CONSEQUENCE SECTOR LEVEL EQUATIONS
C
      DISIM = DISIM + DT*(.03*DISIM)
      RRATE = RRATE + DT*(.05*DP)
      ADAPTD = ADAPTD + DT*DAE
      FACDBL = FACDBL + DT*(.001*PROFND(N2))
      IDISE = IDISE + DT*(DISE)
      IDISI = IDISI + DT*(DISI)
      IDISP = IDISP + DT*(DISP)
      FACGEN = FACGEN + DT*(FUNDSG - FACDOB*FACGEN)
      FACDIS = FACDIS + DT*(FUNDSD-FACDOB*FACDIS)
      PEREN = PEREN + DT*(FACDIS*V(N3)/FACGEN/V(N2) - PEREN)/2.
C
C PROGRAM SECTOR LEVEL EQUATIONS
C
      TRANSP = TRANSP + DT*(.048827*TRANSP)
      AMEDPA = AMEDPA + DT*(.03*AMEDPA)
C
C LEVEL EQUATIONS-POPULATION SECTOR
C     I IS THE INDEX ON THE POPULATION CATEGORY
C     J IS THE INDEX ON THE AGE GROUP
C     K IS THE INDEX ON THE SEX CATEGORY
C
      IF(ICOHRT.NE.1) GO TO 19
      DO 12 I=1,KK
      DO 8 K=1,2
    8 POPOU(I,1,K)=POPOU(I,1,K)+DT*(BR(I,K)-DR(I,1,K)-POPOU(I,1,K)/EX
   1+AR(I,1,K)-RR(I,1,K))
    DO 11 J=2,LL
    DO 11 K=1,2
 11 POPDU(I,J,K)=POPDU(I,J,K)+DT*(POPDU(I,J-1,K)/EX+AR(I,J,K)-
   1    RR(I,J,K)-DR(I,J,K)-POPDU(I,J,K)/EX)
    DO 12 K=1,2
 12 POPDU(I,MM,K)=POPDU(I,MM,K)+DT*(POPDU(I,LL,K)/EX+AR(I,MM,K)-
   1  RR(I,MM,K)-DR(I,MM,K))
    DO 41 J=1,MM
    DO 41 K=1,2
    AAA(J,K) = 0.
    RRR(J,K) = 0.
    DO 41 IN=1,KK
    AAA(J,K) = AAA(J,K) + AR(IN,J,K)
 41 RRR(J,K) = RRR(J,K) + RR(IN,J,K)
    DO 13 K=1,2
 13 POPDU(NN,1,K)=POPDU(NN,1,K)+DT*(BR(NN,K)-DR(NN,1,K)-AAA(1,K)
   1  +RRR  (1,K)-POPDU(NN,1,K)/EX)
    DO 14 J=2,LL
    DO 14 K=1,2
 14 POPDU(NN,J,K)=POPDU(NN,J,K)+DT*(POPDU(NN,J-1,K)/EX-DR(NN,J,K)-
   1  AAA(J,K) + RRR(J,K) - POPDU(NN,J,K)/EX)
    DO 15 K=1,2
 15 POPDU(NN,MM,K)=POPDU(NN,MM,K)+DT*(POPDU(NN,LL,K)/EX-DR(NN,MM,K)-
   1     AAA(MM,K) + RRR(MM,K))
 19 CONTINUE
C
C
C
C LIFE FUNCTION-LEVEL EQUATIONS
C
       DO 60 L=1,5
       DO 60 I=1,KK
   60 LIFEFN(L,I)=LIFEFN(L,I)-DT*(CLFIN(L,I)-CLFNET(L,I))*LIFEFN(L,I)*
     1*2 * ALOG(LIFEFN(L,I))
       TIME = TIME + DT
C
C RATE EQUATIONS-SCENARIO SECTOR
C
3        DV(N1) = NNP * GNNP
         REWM=TABLIE(REWMC,0.0,0.2,5,CI)
         RFCM=TABLIE(RFCMC,.2E4,0.45E4,5,CAP)
         RFDPM=TABLIE(RFDPMC,.6E7,.16E8,5,DP)
         DV(N2) = P * GP(N1)
         TAXR=TAXG*TAX
         DW(N1)=W(N1)*SOFR
         DW(N2)=W(N2) *REFR*REWM*RFCM*RFDPM*60.84
         DW(N5)=W(N5)*EWFR
         DW(NV)=W(NV)*GNNP
         IF(ISCEN.NE.2) GO TO 20
         IF(TIME.GE.1985.) DV(N2) = P * GP(N2)
         IF(TIME.GE.2020.) DV(N2) = P * GP(N3)
20       DV(N3) = DP * GDP(N1)
         IF(TIME.GE.2000.) DV(N3) = DP * GDP(N2)
         DV(N4) = STR * TR
         DV(N5) = 0.
         DV(NV) = EUR   * E
         IF(II.EQ.1) V(N5)=0.051*W(N5)
```

```
      CAP = NNP/P
      U(N4)=U(N2)/NNP
      U(N5)=U(N3)/NNP
      U(NV)=W(NV)/V(N2)
      W(N3)=TAX/NNP
      W(N4)=NNP/W(N5)
      V(N6) = W(N2) / V(N3)
      DU(N2) = GE1(N2) * U(N2)
      IF(TIME.LT.1970.) DU(N2) = GE1(N1) * U(N2)
      DU(N3) = GE2(N2) * U(N3)
      IF(TIME.LT.1970.) DU(N3) = GE2(N1) * U(N3)
      IF(TIME.GE.1974.) GO TO 16
      DV(N1) = .03540*V(N1)
      DV(N2) = .014500*V(N2)
      TAXR=0.05551*TAX
      DW(NV)=0.03602*W(NV)
      DW(N5)=0.017733*W(N5)
      DW(N2)=W(N2)*0.115
      DW(N1)=W(N1)*0.078
      DV(NV)=-0.05*V(NV)
      DV(N4)=0.05*V(N4)
C
C
C RATE EQUATIONS-POPULATION SECTOR
C
   16 IF(ICOHRT.NE.1) GO TO 30
      DO 17 I=1,NN
      DO 17 J=1,MM
      DO 17 K=1,2
      DR(I,J,K)=DRN(I,J,K)*POPDU(I,J,K)
      AR(I,J,K)=ARN(I,J,K)*POPDU(I,J,K)
   17 RR(I,J,K)=RRN(I,J,K)*POPDU(I,J,K)
C
      DO 18 K=1,2
      BR(NN,K) = BRN(NN,K) * P
      DO 18 I=1,KK
   18 BR(I,K) = 0.
C
C
C
C POPULATION SECTOR PLOT ROUTINE
C
      IF(TIMS+TIMPER.GT.TIME) GO TO 30
      TIMS=TIME
      DO 27 I=1,NN
      WRITE(1,32) I,TIME,(NAMES(I,J),J=1,6)
   32 FORMAT(////,30X,'POPULATION TREE FOR CATEGORY',I3,' IN YEAR',
     1F6.0,2X,'NAME:',6A4)
      WRITE(1,33)
   33 FORMAT(' ',29X,'MALES',59X,'FEMALES')
      WRITE(1,36)
      SUMM=0.
      SUMF=0.
      DO 21 J=1,MM
      SUMM=SUMM+POPDU(I,J,1)
   21 SUMF=SUMF+POPDU(I,J,2)
      IF(SUMM.LE.0.) SUMM = .01
      IF(SUMF.LE.0.) SUMF = .01
      DO 26 J=1,MM
      DO 22 N=1,118
   22 LINE(N)=B
      LINE(1) = ZERO
      LINE(2) = ZERO
      LINE(3) = ZERO
      K=15-J
      FRAM=POPOU(I,K,1)/SUMM
      FRAF=POPOU(I,K,2)/SUMF
      LEFT=FRAM*100.*2.+.5
      LRIG=FRAF*100.*2.+.5
      LINE(54)=S
      LINE(65)=S
      DO 23 M=1,2
      LINE(56+M)=AGES(K,M)
   23 LINE(60+M)=AGES(K,M+2)
      LINE(59)=T1
      LINE(60)=T2
      LS=53-LEFT+1
      IR=66+LRIG-1
      IF(LEFT.LE.0) GO TO 37
      IF(LS.LT.4) LS = 4
      DO 24 N=LS,53
   24 LINE(N)=LLL
   37 IF(LRIG.LE.0) GO TO 38
      IF(IR.GT.118) IR = 118
      DO 25 N=66,IR
   25 LINE(N)=R
   38 WRITE(1,34) FRAM,LINE,FRAF
   34 FORMAT('  ',F5.4,118A1,F5.4,'CCO')
      ILL = POPOU(I,K,1)/1000. + .5
      IRR = POPOU(I,K,2) / 1000. + .5
      WRITE(1,35) ILL,LINE,IRR
   35 FORMAT('  ',I5,118A1,I5,'CCO')
   26 CONTINUE
      WRITE(1,36)
   36 FORMAT(' ',T11,'25%',T21,'20%',T31,'15%',T41,'10%',T51,' 5%',T61,
     1'0%  AGE   0%',T81,' 5%',T91,'10%',T101,' 15%',T111,'20%',
     2T121,'25%')
   27 CONTINUE
   30 CONTINUE
C
C LIFE-FUNCTION SECTOR
C
C THIS SECTOR PERFORMS LIFE-FUNCTION ANALYSIS THROUGH A CONSIDERATION OF
C HOW EACH REHABILITATION TECHNOLOGY INTERACTS WITH THE AGE SPECIFIC
C DEMOGRAPHICS OF THE PARTICULAR DISABILITY GROUP(S) TO WHICH THE TECHNOLOG
C CAN BE APPLIED
C             INDICES
C               WORKFORCE PARTICIPITATION INDEX--WPI
C                    WPI =(AVERAGE ANNUAL INCOME)*(YEARS REMAINING IN WORKFORCE)
C                        (NUMBER OF PERSONS REHABILITATED/YEAR)
C               COMMUNITY INTEGRATION INDEX--CII
C                        CII=(AVERAGE YEARS REMAINING IN LIFE)*(NUMBER OF PERS
C                        REHABILITATED/YEAR)
C               AVERAGE LIFE FUNCTION INDICES--ALF
C                    ALF(1)=HEALTH
C                    ALF(2)=SOCIAL-ATTITUDINAL
```

```
C                   ALF(3)=MOBILITY
C                   ALF(4)=COGNITIVE-INTELLECTUAL
C                   ALF(5)=COMMUNICATION
C                   ALF(6)=WPI
C                   ALF(7)=CII
C
C LIFE FUNCTIONS-RATE EQUATIONS
C IN THE FIRST EQUATION BELOW DLFNET IS THE NET CHANGE IN THE ASSOCIATED
C LIFE FUNCTION DUE TO THE FLUX OF INDIVIDUALS LEAVING AND ENTERING THE
C RESPECTIVE DISABLED POPULATION CATEGORY
C
      DO 48 I=1,NN
      PTOT(I)=0.
      RRT(I)=0.
      ART(I)=0.
      DO 48 J=1,MM
      DO 48 K=1,2
      PTOT(I)=PTOT(I)+POPDU(I,J,K)
      RRT(I)=RRT(I)+RR(I,J,K)
   48 ART(I)=ART(I)+AR(I,J,K)
      PTOTAL = 0.
      DO 64 I=1,NN
   64 PTOTAL = PTOTAL + PTOT(I)
      DO 50 L=1,5
      SUM=0.
      DO 49 I=1,KK
   49 SUM=SUM+PTOT(I) *LIFEFN(L,I)
      SUM=SUM+PTOT(NN)
   50 ALF(L)=SUM/PTOTAL
      RRTTT = 0.
      DO 70 I=1,NN
   70 RRTTT = RRTTT + RRT(I)
      RRTT = (3.*RRRT + RRTTT)/4.
      ALF(N6) = AYRW*AAI*PRW*RRTT
      ALF(N7) = AYRL*RRTT
      DO 45 I=1,14
      DO 45 J=1,7
   45 DLFIN(I,J) = DLFFN(I,J)
      DO 61 L=1,5
      DO 61 I=1,KK
      DLFNET(L,I)=((1.-LIFEFN(L,I))*RRT(I)-LFAR(L,I)*ART(I))/PTOT(I)
      DO 61 M=1,20
   61 DLFIN(L,I) = DLFIN(L,I) + TECHNO(L,I,M)*APPOOL(L,I,M)/(COSTPC(I,M)
     1 * PTOT(I))
C
C IN THE ABOVE EQN. TECHNO REPRESENTS THE '%' ACROSS-THE-BOARD INCREASE IN
C LIFE-FUNCTION L DUE TO APPLYING TECHNOLOGY K TO DISABLED CATEGORY I,
C WHEREAS APPOOL(L,I,K)/(COSTPC(I,K)*PTOT(I)) REPRESENTS THE FRACTION OF
C DISABLED POPULATION CATEGORY I TO WHICH THE TECHNOLOGY CAN BE APPLIED
C DUE TO FUNDING LIMITATIONS
C
      DO 62 I=1,KK
      DLFIN(N1,I) = .03
      DLFIN(N2,I) = .01
      DLFIN(N3,I) = .05
      DLFIN(N4,I) = .02
   62 DLFIN(N5,I) = .04
C
```

```
C CONSEQUENCE ANALYSIS SECTOR-RATE AND AUXILIARY EQUATIONS
C THIS SECTOR ENDEAVORS TO CONSIDER THE IMPACTS UPON PARTICULAR SOCIETAL
C CONSEQUENCE VARIABLES
C
C
      DO 1234 IN = 1,5
 1234 DSEMLF(IN) = ALF(IN) + (1. - ALF(IN))/2.
      DISE = (1. - W(N5) / V(N2))*100.
      DISE = W(N5)*100./V(N2)
      DISS = DISSM * DISE / 100.
      DISI = DISIM * DISE / 100.
      DISP = DISPM * DISE / 100.
      DO 1235 IN=1,5
      DISE = DISE*DSEMLF(IN)
      DISI = DISI * DSEMLF(IN)
      DISS = DISS * DSEMLF(IN)
 1235 DISP = DISP * DSEMLF(IN)
      PREAC = SIGN(PEREN,1.)*SQRT(ABS(1.-PEREN))
C
C PROGRAM SECTOR RATE EQUATIONS
C
      DAE = AECONV   * PROFND(N2)
      PROFND(N1) = PIFP*W(N2)
      PROFND(N2)= EDFP*W(N2)
      PROFND(N3) = TCFP*W(N2)
      PROFND(N4) = SDFP*W(N2)
      PROFND(N5) = TRANSP*W(N6)
      PROFND(N6) = AMEDPA * W(N6)
      PROFND(N7) = PROFND(N6) + PROFND(N5)
      TMDS = PROFND(N7)/V(N3)
 9    IF(II.EQ.1) GO TO 6
5     CONTINUE
6     IS = TIME
      CALL OUTP(L,UP,NV,8,1,1,0,0,IS,Z)
      CALL OUTP(W,WP,NV,9,1,1,0,0,IS,Z)
      CALL OUTP(ALF,ALFCM,7,10,1,1,0,0,IS,Z)
      CALL OUTP(PTOT,PTCOM,15,11,1,1,0,0,IS,Z)
      CALL OUTP(CONSF,CONSFP,10,12,1,1,0,0,IS,Z)
      CALL OUTP(PROFND,PROFNP,8,14,1,1,0,0,IS,Z)
      CALL OUTP(V,VP,NV,7,1,1,0,1,IS,Z)
7     CONTINUE
C
C PLOT OF THE SCENARIO VARIABLES
C
      CALL PLOT(NT,8)
C
C PLOT OF THE SCENARIO VARIABLES, PART II
C
      CALL PLOT(NT,9)
C
C
      CALL PLOT(NT,7)
C
C  PLOT OF THE LIFUNCTIONS INDICES, AGGREGATED FOR THE WHOLE POPULATION
C
      CALL PLOT(NT,10)
C
C PLOT OF THE CASE STUDY DISABILITIES
```

```
C
      CALL PLOT(NT,11)
C
C  PLOT OF THE CONSEQUENCE VARIABLES
C
      CALL PLOT(NT,12)
C
C  PLOT OF THE PROGRAM AND POLICY VARIABLES
C
      CALL PLOT(NT,14)
 10   CONTINUE
C
C
      STOP
      END
```

The printing and plotting of all level and auxiliary variables of any system dynamics model is accomplished in FORDYN [25] through utilization of subroutines PREP, OUTP, and PLOT. Subroutine PREP begins the output sequence by reading in tabular headings from cards together with plot variables and symbols. The subroutine prints a heading for the printed table of variables and writes the first two records of information onto scratch disk later to be read and processed by PLOT. A specification of the subroutine arguments is given by the following table.

Table 12: Argument List for Subroutine PREP

Name	Description
P	Array of variable values to be printed and plotted
PN	Dummy array used by PREP
NVARP	Number of variables to be printed or plotted
NT	Disk file number for plot data
J	The jth time PREP has been called
JS	Is a plot desired? 1=yes 0=no
NTYPE	What type of plot is desired? 1=prop. 0=nonprop.
LAST	Is this the last call to prep? 1=yes 0=no

Subroutine OUTP prints the output variables contained within array P at the associated simulation time ISCALE and writes these variables onto scratch disk NT later to be plotted by subroutine PLOT. The argument list is defined below:

Table 13: Argument List for Subroutine OUTP

Name	Description
P	Array representing variables to be printed and plotted
PN	Dummy array used by OUTP

Table 13 cont.

Name	Description
NVARP	No. of variables to be printed
NT	Disk file number on which to write data
J	The jth time OUTP has been called
JS	Is a plot desired? 1=yes 0=no
NTYPE	What type of plot? 1=prop. 0=nonprop.
LAST	Is this the last call to OUTP? 1=yes 0=no
ISCALE	Current simulation time (scaled)
L	Printed output suppression 1=suppress 0=print

Subroutine PLOT reads pertinent plot information from scratch disk file NT and then reads data cards which specify the upper and lower bounds on the plot interval for each variable. The variable values together with their current simulation time ISCALE are then read from disk and plotted one logical record at a time. The argument list is defined below:

Table 14: Argument List for Subroutine PLOT

Name	Description
NPTS	Number of plot points
NT	The scratch disk file number to be read

```
      SUBROUTINE PREP (P,PN,NVARP,NT,J,JS,NTYPE,LAST)
C  **  FORDYN SUBROUTINE      PREP
      DIMENSION P(1),NAME(20),NLET(20),PN(10)
    1 FORMAT (8A10)
    2 FORMAT (5X,10(2X,A10))
    3 FORMAT (2X,4HTIME,9X,A1,9(11X,A1))
    5 FORMAT (22A1)
    7 FORMAT (1X)
      READ(5,1) (NAME(I),I=1,NVARP)
      IF(JS.EQ.1)READ(5,5)IPLUS,IBLANK,(NLET(I),I=1,NVARP)
      IF (J.GT.1) GO TO 6
      WRITE(6,3) (NLET(I),I=1,NVARP)
      IF (NVARP.NE.10) WRITE(6,7)
    6 WRITE(6,2) (NAME(I),I=1,NVARP)
      IF(LAST.EQ.1)WRITE(6,7)
      IF (JS.EQ.0) RETURN
      REWIND NT
      WRITE (NT)NVARP,NTYPE,IPLUS,IBLANK,(NLET(I),NAME(I),I=1,NVARP)
      IF (NTYPE.EQ.0) GO TO 8
      DO 11 I=1,NVARP
   11 PN(I) = P(I)
      GO TO 10
    8 DO 9 I=1,NVARP
    9 PN(I) = 1.0
   10 WRITE (NT) (PN(I),I=1,NVARP)
      RETURN
      END
```

```
      SUBROUTINE OUTP(P,PN,NVARP,NT,J,JS,NTYPE,LAST,ISCALE,L)
C  **  FORDYN SUBROUTINE      OUTP
C THIS ROUTINE PRINTS AND STORES THE ARRAY P
C
      DIMENSION P(10),PN(10),PP(20)
    2 FORMAT(8X,10E12.4)
    4 FORMAT(1X,I4,3X,10E12.4)
    5 FORMAT(1X)
      IF(L.EQ.1) GO TO 7
      IF(J.GT.1) GOTO6
      IF(NVARP.GT.10)GOTO8
      WRITE(6,4) ISCALE,(P(I),I=1,NVARP)
      GOTO7
    8 WRITE(6,4)ISCALE,(P(I),I=1,10)
      WRITE(6,2)(P(I),I=11,NVARP)
      GOTO7
    6 WRITE(6,2)(P(I),I=1,NVARP)
    7 IF(LAST.EQ.1)WRITE(6,5)
      IF(JS.EQ.0)RETURN
      IF(NTYPE.EQ.0)GOTO3
      DO1I=1,NVARP
    1 PP(I)=P(I)/PN(I)
      WRITE(NT) (PP(I),I=1,NVARP),ISCALE
      RETURN
    3 WRITE(NT) (P(I),I=1,NVARP),ISCALE
      RETURN
      END
      SUBROUTINE PLOT (NPTS,NT)
C  **  FORDYN SUBROUTINE      PLOT
C THIS ROUTINE PLOTS ALL DATA FOUND ON FILE NT
      DIMENSION PL(20),NOUT(125),NDUP(20),NAME(20),NO(21),
     1NLET(20),SMALL(20),BIG(20),RANGE(20),NSW(20)
    1 FORMAT (1H1)
    2 FORMAT (1X,E9.3,4E25.3,3X,A10,7X,A1)
    3 FORMAT (1H0,4HTIME,I2,20I5,7X,10HDUPLICATES)
    4 FORMAT (1H0)
    5 FORMAT(1X,F9.3,4F25.3,10X,8HPER CENT)
    6 FORMAT (1X,I4,1X,125A1)
    7 FORMAT (1H0,48X,14HSCALES OF PLOT)
    9 FORMAT (8E10.0)
      WRITE(6,1)
      WRITE(6,7)
      REWIND NT
      READ(NT)NVARP,NTYPE,IPLUS,IBLANK,(NLET(I),NAME(I),I=1,NVARP)
      READ(5,9)(SMALL(I),BIG(I),I=1,NVARP)
      MSW= 0
      DO 10 I=1,NVARP
      IF (SMALL(I).GE.9.0E30) GO TO 11
      NSW(I) = 0
      GO TO 10
   11 NSW (I) = 1
      MSW = MSW +1
   10 CONTINUE
      IF (MSW.EQ.0) GO TO 12
      READ(NT) PL(1)
      DO 13 I=1,NPTS
      READ(NT)(PL(K),K=1,NVARP)
      DO 13 IP=1,NVARP
      IF (NSW(IP).EQ.0) GO TO 13
      SMALL(IP) = AMIN1(SMALL(IP),PL(IP))
      BIG(IP)   = AMAX1(BIG(IP),PL(IP))
   13 CONTINUE
   12 IF (NTYPE.EQ.0) GO TO 14
      SM=9.0E32
      BG = -9.0E32
      DO 15  I=1,NVARP
      SM = AMIN1(SM,SMALL(I))
   15 BG = AMAX1(BG,BIG(I))
      DO 16  I=1,NVARP
      SMALL (I) = SM
   16 BIG(I) = BG
   14 REWIND NT
      IF (NTYPE.NE.2) GO TO 48
      IF (NVARP.EQ.1) GO TO 48
      RANG = 4.0 * (BG - SM)
      ADJ = .75 * RANG / FLOAT(NVARP - 1)
      DO 49 I=1,NVARP
      SMALL(I) = SMALL(I) - ADJ * FLOAT(I-1)
   49 BIG(I) = SMALL(I) + RANG
   48 DO 17 I=1,NVARP
   17 RANGE(I) = BIG(I) - SMALL(I)
      READ(NT)NVARP
      READ(NT)(PL(K),K=1,NVARP)
      DO 18  I=1,NVARP
      QT = RANGE(I) * PL(I)/4.0
      SM = SMALL(I) * PL(I)
      BG = BIG(I) *  PL(I)
      Q1  = SM + QT
      Q2  = Q1 + QT
      Q3  = Q2 + QT
   18 WRITE(6,2)SM,Q1,Q2,Q3,BG,NAME(I),NLET(I)
      IF(NTYPE.NE.1) GO TO 19
      QT = RANGE(1) * 25.0
      SM = SMALL(1) * 100.0
      BG = BIG(1) * 100.0
      Q1 = SM + QT
      Q2 = Q1 + QT
      Q3 = Q2 + QT
      WRITE(6,5)SM,Q1,Q2,Q3,BG
   19 WRITE(6,4)
      J = 1
      NO(1) = 0
      DO 21 I=2,21
   21 NO(I) = NO(I-1) + 5
   20 WRITE(6,3)NO
      IF (J.EQ.2) RETURN
      DO 22  I=1,125
   22 NOUT(I) = IBLANK
      DO 23  I=1,NPTS
      DO 24  IP =1,101,25
   24 NOUT(IP) = IPLUS
      NCOUN = 103
      READ(NT)(PL(K),K=1,NVARP),ISCALE
      DO 25  IP=1,NVARP
      IF(PL(IP).LT.SMALL(IP))  GO TO 25
      IF(PL(IP).GT.BIG(IP)) GO TO 25
      IF(RANGE(IP).LE.0.0) GO TO 25
      NPCT = (PL(IP)- SMALL(IP)) *100.0/RANGE(IP) + 1.5
      NDUP(IP) = NPCT
      IF (IP.EQ.1) GO TO 26
      K = IP-1
      DO 27 M=1,K
      IF (NPCT.NE.NDUP(M)) GO TO 27
      IF (NCOUN.GE.126) GO TO  25
      NOUT(NCOUN) = NLET(M)
      NOUT(NCOUN + 1) = NLET(IP)
      NCOUN = NCOUN + 3
      GO TO 25
   27 CONTINUE
  26  NOUT(NPCT)=NLET(IP)
  25  CONTINUE
      WRITE (6,6) ISCALE,NOUT
      DO 28  IP=1,NVARP
      K=NDUP(IP)
  28  NOUT(K) =IBLANK
      NCOUN=MINO(NCOUN,125)
      DO 23 IP=103,NCOUN
   23 NOUT(IP)=IBLANK
      WRITE(6,4)
      J=2
      GO TO 20
      END
```

Function TABLIE performs linear interpolation between tabular data points specified by the array VAL( ). The argument list is shown below in Table 15.

Table 15: Argument List for Function TABLIE

Name	Description
VAL	Array of tabular values (ordinates)
SMALL	Left-most abscissa corresponding to VAL(1)
DIFF	Uniform difference between abscissas
K	Number of abscissa intervals
DUMMY	The abscissa whose ordinate derivative is to be determined

All of the functions and subroutines subsequently described were taken from the FORDYN package described by Ref. 25.

```
      FUNCTION TABLIE (VAL,SMALL,DIFF,K,DUMMY)
C  **  FORDYN SUBROUTINE     TABLIE
      DIMENSION VAL(21)
      DUM = AMIN1(AMAX1(DUMMY-SMALL,0.0),FLOAT(K)*DIFF)
      I= 1.0 +DUM/DIFF
      IF(I.EQ.K+1) I= K
      TABLIE =(VAL(I+1)-VAL(I))*(DUM-FLOAT(I-1)*DIFF)/DIFF  + VAL(I)
      RETURN
      END
```

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